

Assessment Report: Biological Impairment in the Upper Clark Creek Watershed

**Catawba River Basin
Catawba County, N.C.**

July 2002

**North Carolina Department of Environment and Natural Resources
Division of Water Quality
Planning Branch**

Prepared for the Clean Water Management Trust Fund

Table of Contents

Executive Summary	v
Section 1 – Introduction	1
1.1 Study Area Description	1
1.2 Study Purpose	1
1.3 Study Approach and Scope	2
1.3.1 Study Approach	4
1.3.2 Approach to Management Recommendations	4
1.3.3 Data Acquisition	5
Section 2 – Description of the Clark Creek Watershed	7
2.1 Introduction	7
2.2 Streams	7
2.3 Topography and Geology	8
2.4 Subwatershed Delineation	9
2.5 Land Use in the Watershed	9
2.6 Sources of Pollution	11
2.6.1 Point Sources	11
2.6.2 Nonpoint Sources	13
2.6.3 Historical Issues	17
2.7 Trends in Land Use and Development	17
2.8 Regulatory Issues and Local Water Quality Activities	17
Section 3 – Potential Causes of Biological Impairment	21
3.1 Key Stressors to be Evaluated in the Clark Creek Watershed	21
Section 4 – Biological Conditions and Stream Habitat	23
4.1 Approach to Biological and Habitat Assessment	23
4.1.1 Benthic Community Sampling and Rating Methods	24
4.1.2 Habitat Assessment Methods	25
4.2 Findings	25
4.2.1 Description	25
4.2.2 Summary of Conditions and Nature of Impairment	27
Section 5 – Chemical and Toxicological Conditions	29

5.1	Approach to Chemical, Physical and Toxicity Sampling	29
5.1.1	<i>General Approach</i>	29
5.1.2	<i>Site Selection</i>	31
5.2	Water Quality Characterization.....	32
5.3	Stressor and Source Identification	35
5.3.1	<i>Toxicity: Project Data</i>	35
5.3.2	<i>Toxicity: Other Data</i>	39
5.3.3	<i>Dissolved Oxygen</i>	40
5.3.4	<i>Source Area Evaluation</i>	40
Section 6 – Channel and Riparian Conditions		43
6.1	Summary of Existing Conditions	43
6.1.1	<i>Overall Channel and Riparian Condition</i>	43
6.1.2	<i>Channelization and Hydrologic Impacts</i>	46
6.2	Future Changes.....	46
Section 7 – Analysis and Conclusions: Causes and Sources of Impairment		47
7.1	Analyzing Causes of Impairment.....	47
7.1.1	<i>A Framework for Causal Evaluation—the Strength of Evidence Approach</i>	47
7.1.2	<i>Candidate Stressors</i>	48
7.1.3	<i>Review of Evidence</i>	48
7.1.4	<i>Conclusion</i>	52
7.2	Sources of Impairment	52
7.3	Other Issues of Concern	54
Section 8 – Improving Stream Integrity in Clark Creek: Recommended Strategies		55
8.1	Addressing Current Causes of Impairment.....	55
8.1.1	<i>Habitat Degradation--Sedimentation and Substrate Instability</i>	55
8.1.2	<i>Chlorine Toxicity from the Newton WWTP</i>	61
8.1.3	<i>Toxicity in the Headwaters Area</i>	61
8.2	Addressing Future Threats	62
8.2.1	<i>Sediment from New Construction</i>	62
8.2.2	<i>Hydromodification Due to Increased Stormflows</i>	63
8.2.3	<i>Riparian Buffers</i>	63
8.2.4	<i>Pesticides and Nutrients</i>	63
8.3	A Framework for Improving and Protecting Stream Integrity.....	64
8.4	Summary of Watershed Strategies for Clark Creek.....	64
Section 9 – References		67

APPENDICES

- A. Benthic Macroinvertebrate Sampling
- B. Water Quality Conditions
- C. Land Use Data
- D. Channel and Riparian Conditions

Executive Summary

Introduction

This report presents the results of the upper Clark Creek water quality assessment, conducted by the North Carolina Division of Water Quality (DWQ) with financing from the Clean Water Management Trust Fund (CWMTF). Clark Creek is considered impaired by the DWQ because it is unable to sustain an acceptable community of aquatic organisms, indicating that the stream does not fully support its designated uses. The goal of the assessment is to provide the foundation for future water quality restoration activities in the upper Clark Creek watershed by: 1) identifying the most likely causes of biological impairment; 2) identifying the major watershed activities and pollution sources contributing to those causes; and 3) outlining a general watershed strategy that recommends restoration activities and best management practices (BMPs) to address the identified problems.

Study Area and Stream Description

Clark Creek drains a 91-square mile watershed, flowing from its headwaters in the City of Hickory southward through Newton and Maiden before joining the South Fork Catawba River in Lincolnton, NC (see Figure in Section 1). The 39-square mile study area, located entirely within Catawba County, comprises the northern portion of the Clark Creek watershed and includes the mainstem and all tributaries upstream of the confluence with Pinch Gut Creek, west of Maiden. The upper portion of the study area (upstream of Southside Park in Newton) is primarily a mixture of industrial, commercial and residential uses. An estimated 21% of this area is covered by impervious surfaces such as roads and buildings. The lower portion of the study area (between Southside Park and Pinch Gut Creek) has significant agricultural and residential uses and an estimated imperviousness of 11%. The Newton wastewater treatment plant discharges to Clark Creek in the downstream part of the study area. In the early twentieth century, Clark Creek was channelized (dredged and straightened) for virtually its entire length to improve drainage of agricultural lands. More recently, substantial development has occurred in the upper portion of the study area, especially in the Interstate 40 corridor. The study area is described in more detail in Section 2.

Benthic macroinvertebrate communities are impaired throughout the mainstem of Clark Creek. Habitat is generally poor. The streambed is comprised largely of unstable sand deposits and bank erosion is widespread.

Approach

A wide range of data was collected to evaluate potential causes and sources of impairment. Data collection activities included: benthic macroinvertebrate sampling; assessment of stream habitat, morphology, and riparian zone condition; water quality sampling to evaluate stream chemistry and toxicity; characterization of watershed land use, conditions and pollution sources. Data collected during the study are presented in Sections 2, 4, 5 and 6 of the report.

Conclusions

The most probable causes and sources of impairment, based upon an evaluation of all available data, are the following (see Section 7 for additional discussion):

1. Widespread habitat degradation, manifested by extensive sedimentation and instability, is a primary cause of the impaired biological conditions throughout much of the study area. This habitat degradation is due to a combination of factors that have been at work for a number of decades: the direct effects of channelization (channel dredging and straightening); subsequent stream channel instability due to gradual morphological adjustment to channelized conditions; changes in watershed hydrology following increased development.
2. Toxicity from nonpoint sources (industrial and commercial areas), together with scour (high velocity stormwater flows) and limited recolonization potential, act cumulatively to cause impairment in the Clark Creek headwaters. While it is possible that toxic impacts from these sources extend further downstream, there is currently no significant evidence that this is the case.
3. Toxicity due to chlorine discharged from the Newton WWTP is a likely cause of impairment for at least a mile below the outfall.

Recommendations

The most important factors leading to impairment in the study area are systemic in nature. Addressing these problems will require actions that are similarly broad in scope. Mitigating the potential impacts of future watershed development on watershed hydrology is also critical, or improvements resulting from efforts to control current sources of impairment may be short lived.

The following actions are necessary to address current sources of impairment in Clark Creek and prevent future degradation (see Section 8 for additional details). Actions one through six are all essential to the restoration of aquatic communities throughout Clark Creek. Action seven is essential to improvement in the lower portion of the study area below the Newton WWTP. The remaining actions should also be implemented, but will result in limited improvement unless the first seven are also accomplished.

1. **Over the long run, extensive stream channel restoration activities and stormwater retrofit BMPs should be implemented throughout the watershed.** This will involve a substantial effort that would likely take several decades to fully implement.
 - a) Approximately ten miles of Clark Creek within the study area (and another ten miles downstream of the study area), as well as many tributary channels, should be restored to a stable morphology.
 - b) BMPs to reduce stormwater runoff volume and partially restore watershed hydrology should be implemented in the existing developed areas of the Clark headwaters, Miller Branch, Cline Creek, Hildebran Creek and Town Creek drainages.
2. **These activities should be implemented deliberately and incrementally over time:**
 - a) Work should be carried out first in tributary and headwaters subwatersheds. Restoration of the mainstem of Clark Creek should be approached later when upstream sediment sources have been reduced and upstream hydrologic conditions have been mitigated to the extent practical.
 - b) Channel restoration and stormwater BMPs should be implemented in an integrated fashion so that both channel morphology and watershed hydrology problems are addressed using a coordinated approach in each subwatershed.

- c) Local governments and other stakeholders should develop the cooperative organizational framework necessary to carry out the watershed planning, project design, implementation and monitoring activities that will be necessary to sustain this effort over time.
3. **The five-square mile Cline Creek subwatershed should serve as the focus for initial planning and project activities.** Costs are likely to exceed \$1 million per square mile of watershed. Activities should include:
- a) Restoring the mainstem of Cline Creek to a stable morphology from at least US 321 to its mouth, a distance of approximately 1.5 miles.
 - b) Evaluating and implementing channel restoration opportunities on major tributaries.
 - c) Implementing stormwater BMPs to control runoff volume and peak flows from existing developed areas, especially commercial and industrial areas upstream of US 321. The selection of specific BMP types and locations will require watershed planning and site-specific engineering evaluations.
 - d) Encouraging property owners along all streams to replant native riparian vegetation.
4. **Post-construction stormwater management should be required for all new development in the study area in order to prevent further channel erosion and continued habitat degradation** due to additional uncontrolled stormwater inputs. These requirements should include active promotion of infiltration practices and other approaches to limit stormwater volume, and no net increase in peak flows over predevelopment conditions for the 1-year 24-hour storm. Measures could be implemented through the Phase II stormwater program or through other local initiatives.
5. Whether accomplished through incentives or regulatory measures, **it is important that existing riparian buffers be protected.**
6. **In order to prevent future water quality deterioration related to new construction activities, sediment and erosion control practices should be improved.** The Division of Land Resources and the City of Newton's Erosion and Sediment Control Program should review their current tools and implementation to determine how erosion and sedimentation control efforts can be improved in this watershed.
7. The Division of Water Quality should ensure that chlorine concentrations in the Newton WWTP effluent are reduced to nontoxic levels. This facility should receive a chlorine limit as soon as possible, and in-stream chlorine concentrations should be carefully evaluated to determine if further action is necessary.
8. The headcut in Clark Creek near the Martin Marietta quarry above I-40, of unknown origin, should be stabilized to prevent further erosion and sediment loading to the stream.
9. A watershed education program should be developed and implemented with the goal of targeting homeowners and managers of commercial and industrial facilities in order to reduce current stream damage and prevent future degradation. At a minimum, the program should address:

- a) redirecting downspouts to pervious areas rather than routing these flows to driveways or gutters;
 - b) protecting existing wooded riparian areas on ephemeral streams;
 - c) replanting native riparian vegetation on perennial, intermittent and ephemeral channels where such vegetation is absent; and
 - d) reducing and properly managing pesticide and fertilizer use.
10. Additional data should be obtained to more narrowly define the nature and source of toxicants impacting the headwaters of Clark Creek. Periodic monitoring of the headwaters area should be carried out to determine if other ongoing activities (elimination of illegal discharges by Hickory as part of the Phase II stormwater program; BMPs intended to control stormwater volumes) lead to improvements in the benthic community.

Section 1

Introduction

This report presents the results of the Clark Creek water quality assessment, conducted by the North Carolina Division of Water Quality (DWQ) with financing from the Clean Water Management Trust Fund (CWMTF). Clark Creek is considered impaired by the DWQ because it is unable to support an acceptable community of aquatic organisms. The reasons for this condition have been previously unknown, inhibiting efforts to improve stream integrity in this watershed.

Part of a larger effort to assess impaired streams across North Carolina, this study was intended to evaluate the causes of biological impairment and to suggest appropriate actions to improve stream conditions. The CWMTF, which allocates grants to support voluntary efforts to address water quality problems, is seeking DWQ's recommendations regarding the types of activities it could fund in these watersheds to improve water quality. Both the DWQ and the CWMTF are committed to encouraging local initiatives to protect streams and to restore degraded waters.

1.1 Study Area Description

Clark Creek is located in Catawba and Lincoln counties, in the Catawba River basin (Figure 1.1). The stream's headwaters are within the City of Hickory, north of I-40. It drains a 91-square mile watershed, flowing southward through Newton and Maiden before joining the South Fork Catawba River at Lincolnton, NC. The 39-square mile (100 sq. km) area under current study comprises the northern portion of the watershed and includes the mainstem and all tributaries upstream of the confluence with Pinch Gut Creek. The study area lies entirely within Catawba County. While Clark Creek is impaired for virtually its entire length, the present study focuses on this upper portion of the watershed, where wastewater inputs are limited and nonpoint source problems are likely to predominate. Most of the study area is upstream of any point sources of domestic or industrial wastewater, although the Newton wastewater treatment plant (WWTP) discharges to Clark Creek in the lower part of the study area. Additional treated wastewater discharges occur downstream of the study area. The upper half of the study watershed is predominantly urban and suburban, while the lower half is suburban and rural. Clark Creek lies within DWQ subbasin 03-08-35.

1.2 Study Purpose

The Clark Creek assessment is part of the Watershed Assessment and Restoration Project (WARP), a study of eleven watersheds across the state being conducted during the period from 2000 to 2002 with funding from the CWMTF (Table 1.1). The goal of the project is to provide the foundation for future water quality restoration activities in the eleven watersheds by:

1. Identifying the most likely *causes* of biological impairment (such as degraded habitat or specific pollutants).

2. Identifying the major watershed activities and *sources* of pollution contributing to those causes (such as stream bank erosion or stormwater runoff from particular urban or rural areas).
3. Outlining a watershed *strategy* that recommends restoration activities and best management practices (BMPs) to address the identified problems and improve the biological condition of the impaired streams.

This investigation focused primarily on aquatic life use support issues. It was intended to assess the major issues related to biological impairment as comprehensively as possible within the time frame of the study. While not designed to address other important issues in the Clark Creek watershed, such as bacterial contamination or flooding, the report discusses those concerns where existing information allows.

Table 1.1 Study Areas Included in the Watershed Assessment and Restoration Project

Watershed	River Basin	County
Toms Creek	Neuse	Wake
Upper Swift Creek	Neuse	Wake
Little Creek	Cape Fear	Orange, Durham
Horsepen Creek	Cape Fear	Guilford
Little Troublesome Creek	Cape Fear	Rockingham
Upper Clark Creek	Catawba	Catawba
Upper Cullasaja River/Mill Creek	Little Tennessee	Macon
Morgan Mill/Peter Weaver Creeks	French Broad	Transylvania
Mud Creek	French Broad	Henderson
Upper Conetoe Creek	Tar-Pamlico	Edgecombe, Pitt, Martin
Stoney Creek	Neuse	Wayne

1.3 Study Approach and Scope

Of the study's three objectives, identification of the likely causes of impairment is a critical building block, since addressing subsequent objectives depends on this step (Figure 1.2). Determining the primary factors causing biological impairment is a significant undertaking that must address a variety of issues (see the Background Note "Identifying Causes of Impairment"). While identifying causes of impairment can be attempted using rapid screening level assessments, we have taken a more detailed approach in order to maximize the opportunity to reliably and defensibly identify causes and sources of impairment within the time and resource framework of the project. This provides a firmer scientific foundation for the collection and evaluation of evidence, facilitates the prioritization of problems for management, and offers a more robust basis for the commitment of resources. EPA's recently published guidance for stressor identification envisions that causes of impairment be evaluated in as rigorous a fashion as is practicable (USEPA, 2000).

Background Note: Identifying Causes of Impairment

Degradation and impairment are not synonymous. Many streams and other waterbodies exhibit some degree of degradation, that is, a decline from unimpacted conditions. Streams that are no longer pristine may still support good water quality conditions and function well ecologically. When monitoring indicates that degradation has become severe enough to significantly interfere with one of a waterbody's designated uses (such as aquatic life propagation or water supply), the Division of Water Quality formally designates that stream segment as impaired. It is then included on the State's 303(d) list, the list of impaired waters in North Carolina.

Many impaired streams, including those that are the subject of this study, are so rated because they do not support a healthy population of fish or benthic macroinvertebrates (aquatic bugs visible to the naked eye). While standard biological sampling can determine whether a stream is supporting aquatic life or is impaired, the cause of impairment can only be determined with additional investigation. In some cases a potential cause of impairment is noted when a stream is placed on the 303(d) list, using the best information available at that time. These noted potential causes are generally uncertain, especially when nonpoint source pollution issues are involved.

A cause of impairment can be viewed most simply as a stressor or agent that actually impairs aquatic life. These causes may fall into one of two broad classes: 1) chemical or physical pollutants (e.g., toxic chemicals, nutrient inputs, oxygen-consuming wastes); and 2) habitat degradation (e.g., loss of in-stream structure such as riffles and pools due to sedimentation; loss of bank and root mass habitat due to channel erosion or incision). Sources of impairment are the origins of such stressors. Examples include urban and agricultural runoff.

The US Environmental Protection Agency defines causes of impairment more specifically as “those pollutants and other stressors that contribute to the impairment of designated uses in a waterbody” (USEPA, 1997, p 1-10). When a stream or other waterbody is unable to support an adequate population of fish or macroinvertebrates, identification of the causes of impairment thus involves a determination of the factors most likely leading to the unacceptable biological conditions.

All conditions which impose stress on aquatic communities may not be causes of impairment. Some stressors may occur at an intensity, frequency and duration that are not severe enough to result in significant degradation of biological or water quality conditions to result in impairment. In some cases, a single factor may have such a substantial impact that it is the only cause of impairment, or clearly predominates over other causes. In other situations, several major causes of impairment may be present, each with a clearly significant effect. In many cases, individual factors with predominant impacts on aquatic life may not be identifiable and the impairment may be due to the cumulative impact of multiple stressors, none of which is severe enough to cause impairment on its own.

The difficulty of developing linkages between cause and effect in water quality assessments is widely recognized (Fox, 1991; USEPA, 2000). Identifying the magnitude of a particular stressor is often complex. Storm-driven pollutant inputs, for instance, are both episodic and highly variable, depending upon precipitation timing and intensity, seasonal factors and specific watershed activities. It is even more challenging to distinguish between those stressors which are present, but not of primary importance, and those which appear to be the underlying causes of impairment. Following are examples of issues which must often be addressed.

- Layered impacts (Yoder and Rankin, 1995) may occur, with the severity of one agent masking other problems that cannot be identified until the first one is addressed.
- Cumulative impacts, which are increasingly likely as the variety and intensity of human activity increase in a watershed, are widely acknowledged to be very difficult to evaluate given the current state of scientific knowledge (Burton and Pitt, 2001; Foran and Ferenc, 1999).
- In addition to imposing specific stresses upon aquatic communities, watershed activities can also inhibit the recovery mechanisms normally used by organisms to ‘bounce back’ from disturbances.

For further information on use support and stream impairment issues, see the web site of DWQ's Basinwide Planning Program, at <http://h2o.enr.state.nc.us/basinwide/index.html>; *A Citizen's Guide to Water Quality Management in North Carolina* (NCDWQ, 2000); EPA's *Stressor Identification Guidance Document* (USEPA, 2000).

1.3.1 Study Approach

The general conceptual approach used to determine causes of impairment in Clark Creek was as follows (see Foran and Ferenc, 1999; USEPA, 2000).

- *Identify the most plausible potential (candidate) causes* of impairment in the watershed, based upon existing data and initial watershed reconnaissance activities.
- *Collect a wide range of data* bearing on the nature and impacts of those potential causes.
- *Characterize the causes of impairment* by evaluating all available information using a *strength of evidence approach*. The strength of evidence approach, discussed in more detail in Section 7, involves a logical evaluation of multiple lines (types) of evidence to assess what information supports or does not support the likelihood that each candidate stressor is actually a contributor to impairment.

Project goals extended beyond identifying causes of impairment, however, and included the evaluation of source activities and the development of recommendations to mitigate the problems identified. In order to address all three objectives, activities conducted in the Clark Creek watershed during this study were divided into three broad stages (Figure 1.2):

1. An initial *reconnaissance stage*, in which existing information was compiled and watershed reconnaissance conducted. At the conclusion of this stage the most plausible candidate causes of impairment were identified for further evaluation.
2. A *stressor-source evaluation stage* that included: collection of information regarding candidate causes of impairment; evaluation of all available information using a strength of evidence approach; investigation of likely sources (origins) of the critical stressors.
3. The *development of strategies* to address the identified causes of impairment.

1.3.2 Approach to Management Recommendations

One of the goals of this assessment was to outline a course of action to address the key problems identified during the investigation, providing local stakeholders, the CWMTF and others with the information needed to move forward with targeted water quality improvement efforts in this watershed. It is DWQ's intent that the recommendations included in this document provide guidance that is as specific as possible given available information and the nature of the issues to be addressed. Where problems are multifaceted and have occurred over a long period of time, the state of scientific understanding may not permit all actions necessary to mitigate those impacts to be identified in advance. In such situations an iterative process of 'adaptive management' (Reckhow, 1997; USEPA, 2001) is required, in which those committed to stream improvement efforts begin with implementation of an initial round of management actions, followed by monitoring to determine what additional measures are needed.

Protection of streams from additional damage due to future watershed development or other planned activities is a critical consideration. In the absence of such protection, efforts to restore water quality by mitigating existing impacts will often be ineffective or have only a temporary impact. These issues were examined during the course of the study and addressed in the management recommendations.

Management recommendations included in this document are not intended to be institutionally prescriptive. It is not the objective of this study to specify particular administrative or institutional mechanisms for implementing remedial practices, but only to describe the types of actions that must occur to place Clark Creek on the road to improvement. It is DWQ's hope that local governments and other stakeholders in the Clark Creek watershed will work cooperatively with each other and with state agencies to implement these measures in cost-effective ways.

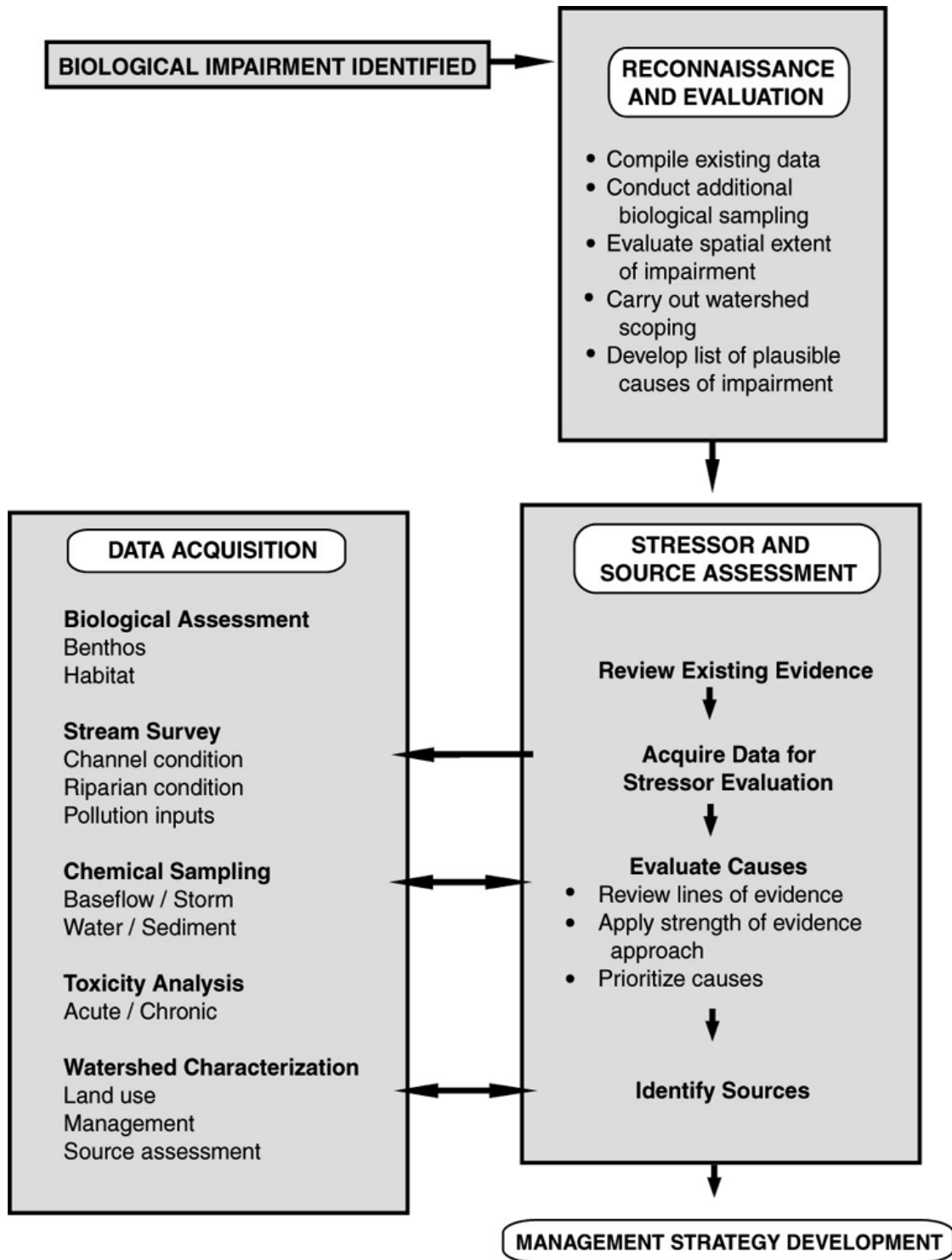
The study did not develop TMDLs (total maximum daily loads) or establish pollutant loading targets. For many types of problems (e.g., most types of habitat degradation), TMDLs may not be an appropriate mechanism for initiating water quality improvement. Where specific pollutants are identified as causes of impairment, TMDLs may be appropriate and necessary if the problem is not otherwise addressed expeditiously.

1.3.3 Data Acquisition

While project staff made use of existing data sources during the course of the study, these were not adequate to fully address the goals of the investigation. Extensive data collection was necessary to develop a more adequate base of information. The types of data collected during the study included:

1. Macroinvertebrate sampling.
2. Assessment of stream habitat, morphology, and riparian zone condition.
3. Stream surveys--walking stream channels to identify potential pollution inputs and obtain a broad scale perspective on channel condition.
4. Chemical sampling of stream water quality.
5. Bioassays to assess water column toxicity.
6. Watershed characterization--evaluation of watershed hydrologic conditions, land use, land management activities, and potential pollution sources.

Figure 1.2 Overview of Study Activities



Section 2

Description of the Clark Creek Watershed

2.1 Introduction

The study area (Figure 1.1) consists of the watershed of Clark Creek and its tributaries upstream of the confluence with Pinch Gut (Hydrologic Unit 03050102030010). The total drainage area is 39 square miles (100 sq. km), representing 44% of the entire Clark Creek watershed.

Approximately 28% of the study area lies within the corporate limits of Newton, while 12%, 7% and 2% lie within Hickory, Conover and Maiden, respectively. The remaining 51% of the study area is comprised of unincorporated portions of Catawba County. This section summarizes watershed hydrography and topography, describes current and historical land use, and discusses potential pollutant sources.

2.2 Streams

The mainstem of Clark Creek in the study area (Figure 2.1) is joined by the following major tributaries, in order from upstream to downstream: Miller Branch, Cline Creek, Hildebran Creek, Town Creek, Bills Branch and Betts Branch. The term “urban stream” could be applied to the headwaters and all major tributaries except Bills Branch, Betts Branch and Smyre Creek (a tributary of Town Creek). These exceptions have predominantly suburban and rural watersheds. No significant impoundments are present on Clark Creek or its main tributaries within the study area.

Within the study area, Clark Creek and its tributaries are classified by the State of North Carolina as C waters. The South Fork Catawba, downstream of the Clark Creek confluence, is a water supply source for the communities of Lincolnton, Gastonia, Dallas, Bessemer City, Ranlo, Cherryville and Stanly. Further downstream, the South Fork Catawba joins the Catawba River at Lake Wylie, a 13,000+ acre (5020 hectare) reservoir built by Duke Power Company in the 1920's.

North Carolina's 2000 303(d) list records Clark Creek as biologically impaired from SR 1149 (in Newton, below the confluence with Cline Creek) to its mouth, a distance of approximately 14.7 miles (23.5 km). Fecal coliform, copper and turbidity are listed as problem parameters for a 1.7-mile (2.7 km) section of the creek downstream of the study area. The reasons for biological impairment in the study area had not been determined prior to the study.

A significant event in the history of Clark Creek was its channelization, beginning in 1909. As chronicled in the *Newton Enterprise*, a local newspaper, a steam shovel mounted on a barge was floated down Clark Creek, straightening, deepening and widening the stream from the confluence of Miller Branch, north of I-40, all the way to the confluence with the South Fork Catawba. Where bedrock outcrops were encountered, blasting was employed to achieve the prescribed channel dimensions. The purpose of this action was to drain the flat bottomlands along the stream, benefiting agriculture and reducing malarial mosquito habitat.

The channelization was initiated by farmers who could no longer cultivate the bottomlands, as flooding and drainage problems had increased due to massive sedimentation caused by clearing of the uplands in the watershed. The channelization was reinforced by dredging of the main tributaries for varying distances upstream from their confluence with the mainstem. The process was then repeated in the 1920's, resulting in the current straight, non-meandering path of the stream through its valley (Exhibit 2.1). However logical and progressive the channelization project was in its day, it has had enduring effects on the habitat of the stream. These effects are discussed in several of the later sections of this report. [DWQ is indebted to Mr. Alex Floyd of the Catawba County Library in Newton for researching back issues of the *Newton Enterprise* and gleaning details of this story].



Exhibit 2.1 Typical Clark Creek channel section

2.3 Topography and Geology

The headwaters of Clark Creek are located within the City of Hickory, just north of Interstate 40, at an elevation of about 1100 feet (335 m) above mean sea level (msl). Topography is typical Piedmont rolling hills, highly dissected by stream drainages. The underlying geology is gneiss and schist (metamorphosed igneous rocks) of the Inner Piedmont Belt. The direction of flow is toward the southeast, then south, with a slope of about 30 feet per mile (0.6%). At the downstream end of the study area the elevation is near 800 feet (244 m) msl.

Precipitation averages 43 inches (1092 mm) per year (data from the Charlotte Airport), with a fairly even distribution among months. Stream discharge in this area averages 1.5 cubic feet per second (cfs) per square mile on an annual basis, and streams are less prone to become dry during drought conditions, compared to streams in other hydrologic areas in North Carolina (Geise and Mason, 1991). Drainage areas of 0.5 square mile or less in this part of the state are generally sufficient to support 7Q10 flows greater than zero (Geise and Mason, 1991).

Soils that make up the riparian zones of the mainstem and major tributaries of Clark Creek are poorly to moderately drained and fine sandy loam in texture. These soils, from the Chewacla, Congaree and Wehadkee Series (Brewer, 1975), are nearly level, floodplain soils formed in recent acidic alluvium. For the most part, the riparian zones, as defined by the soil type, are no

greater than 250 feet in width with many stream stretches bordered by more narrow zones. Upland soils are in the Hiwassee-Cecil Association. These are acidic, deep, well-drained upland type sandy clays and clay loam located on moderately steep ridge tops and side slopes.

2.4 Subwatershed Delineation

For the purposes of this study, the 39-square mile study area was divided into two subwatersheds of approximately equal size (Figure 2.1):

1. Upper drainage. The mainstem and tributaries upstream of Southside Park in Newton (upstream of the confluence with Town Creek). The upper subwatershed includes most of the highly developed portions of the study area and has a drainage area of 21 square miles. The following major tributaries are included:

Miller Branch	1.9 square miles
Cline Creek	5.1 square miles
Hildebran Creek	3.5 square miles

2. Lower drainage. The mainstem and tributaries downstream of Southside Park in Newton but upstream of W. Maiden Road (SR 2007). This area (total drainage 18 square miles) includes the following tributaries:

Town Creek	7.5 square miles
Bills Branch	2.6 square miles
Betts Branch	3.7 square miles

2.5 Land Use in the Watershed

Starting in the mid-1800's, the entire drainage area was cleared of trees and then intensively farmed for cotton, tobacco, corn and small grains. Significant erosion of topsoils occurred, especially on the steeper topography. Subsequent planting of pine trees on these gullied slopes, along with natural reversion of old fields to forestland, has reduced the loss of soil to the streams. Much of the soil eroded from hillsides was deposited in the floodplains of streams like Clark Creek, and these floodplains or bottomlands are now quite favorable sites for pasture and turf farming. Textile and furniture manufacturing were introduced into the Hickory and Newton areas around 1900 (Preslar, 1954) and have been a significant part of the area's industrial base through much of the 20th Century.

Current land use within the study area is a mixture of urban and built-up areas, pastureland, forestland and cropland. Land use maps for the upper and lower portions of the study area, based on 1998 aerial photography, are shown in Figures 2.2 and 2.3, respectively. Starting at the headwaters, the first two miles of the mainstem in Hickory and Cline Creek in Conover have drainage areas dominated by industrial and commercial development and include major highways, stormwater discharges, a quarry and major active construction projects. Further downstream, the municipality of Newton, along with suburban residential development,

dominates much of the study area drainage. Tributaries in the lower portion of the study area have substantial cropland, pastureland and forest. Soybeans, corn and hay are the primary crops.

These differences between the upper and lower portions of the study area are reflected in the land use distribution, shown in Table 2.1.

- Developed areas (residential, commercial and industrial areas, plus roads and railroads) are significant, accounting for 48% of the land use in the upper study area and 36% of the lower study area.
- Commercial and industrial development (over 20%) exceeds residential use (17%) in the upper subwatershed.
- In the lower subwatershed, residential areas (24%) predominate over industrial and commercial uses (6%).
- Active cropland is much more significant in the lower subwatershed than in the upper subwatershed (26% and 9%, respectively).
- The extent of forest and wooded areas was similar in both portions of the study area (29%).

Table 2.1 Land Use in the Clark Creek Study Area—1998

Land Use Category	Upper Study Area*		Lower Study Area*	
	Square Miles	%	Square Miles	%
Impervious (roads, rock) and Railroad ROW	2.2	10.2	1.1	5.8
Commercial	1.9	8.8	0.4	2.0
Industrial	2.5	11.8	0.7	4.0
Residential (1/4 and 1/2 acre)	1.1	5.4	0.8	4.2
Residential (1 and 2 acre)	2.5	11.9	3.7	19.9
Bare soil (e.g., fallow field; construction site)	0.9	4.5	0.04	0.2
Agriculture: active cropland	1.8	8.6	4.9	26.4
Grass land (pasture; meadow; open grass)	1.9	8.9	1.4	7.5
Forest and Wooded Land	6.2	29.4	5.5	29.4
Water	0.1	0.5	0.1	0.6
TOTAL	21.2	100.0	18.7	100.0

* Upper study area is upstream of Southside Park in Newton and the mouth of Town Creek. Lower study area lies between Southside Park and the mouth of Pinch Gut Creek and includes Town Creek.

Source: Catawba County Planning Department. GIS data based on 1998 aerial photography (see Appendix C).

Impervious surfaces (areas such as rooftops, roads and parking lots that prevent infiltration of precipitation into the soil) covered approximately 20% of the upper study area in 1998, with a number of smaller drainages exceeding that amount (Table 2.2). About 39% of the impervious coverage in the upper study area was directly associated with industrial and commercial activities (rooftops and parking only--roads not included). Consistent with its land use characteristics, imperviousness in the lower study areas was only 11%. The land use database and the calculation of impervious cover are described further in Appendix C.

In the upper drainage as a whole, imperviousness has reached the levels where severe impacts to stream biota can generally be expected (Schueler, 1994). Stormwater management practices (e.g., detention ponds or infiltration practices), which could slow the rate of storm runoff from these impervious areas, are not required nor commonly used in the Clark Creek drainage.

Table 2.2 Estimated Percent Impervious Cover in Clark Creek Subwatersheds-1998

Subwatershed	Percent Impervious Cover
Upper Study Area	20%
Clark headwaters (above Miller Br.)	29%
Miller Branch	21%
Cline Creek	21%
Hildebran Creek	25%
Remainder of Upper Area	12%
Lower Study Area	11%
Town Creek (incl. Smyre Ck.)	14%
Bills Branch	11%
Betts Branch	9%
Remainder of Lower Area	9%

Source: see Appendix C.

2.6 Sources of Pollution

2.6.1 Point Sources

Wastewater Discharges. The lower mainstem receives treated wastewater from the City of Newton's Clark Creek Wastewater Treatment Plant (NPDES Permit No. NC0036196). This facility treats both domestic and industrial wastewaters from parts of Hickory, Conover and Newton, discharging its effluent into Clark Creek upstream of Rome Jones Road (SR 2012). The plant is permitted to discharge up to a monthly average of 5.0 million gallons per day (MGD) of treated wastewater and currently receives up to 1.28 MGD of pretreated industrial wastewater. Of the nine contributing industrial facilities, six are textiles, two are metals processing, and one is sludge composting.

Review of the WWTP's monitoring reports from January 2000 through September 2001 showed actual discharge flow rates ranging from a monthly average of 2.7 to 3.8 MGD. The plant had no violations of any of its permitted discharge limits during this period. Additional data on the WWTP's effluent, based on self-monitoring data reported to DWQ, are presented in Table 2.3. The discharge represents a substantial portion of the flow in Clark Creek during dry weather. Clark Creek above the WWTP has a 7Q10 of 3.88 MGD (6 cfs).

The facility is required to perform whole effluent toxicity testing on a quarterly basis using an in-stream waste concentration of 56%. These are 7-day chronic toxicity tests utilizing *Ceriodaphnia dubia*, a microcrustacean. The plant has passed all such tests since March 1997.

Two other facilities, both operated by the City of Conover, formerly discharged domestic wastewater into the upper portion of the study area, but have since connected to the Newton WWTP. The Conover Southwest WWTP discharged to a tributary of Cline Creek until 1993, while the Fairgrove WWTP discharged into Clark Creek above the Cline Creek confluence until 1989. Each of these former facilities had a permitted wasteflow of 0.1 MGD.

Color has been an issue in the South Fork Catawba drainage, including Clark Creek, for some time. While most of the facilities involved are downstream of the study area, color periodically discharged from the Newton WWTP has also been a concern. In 2001, a color strategy was implemented for eight dischargers in the South Fork drainage. The strategy was not applied to the Newton WWTP, although the facility is required to monitor color monthly during the summer.

As part of a toxics review for the South Fork Catawba River, DWQ completed a draft review of toxics data for the Clark Creek watershed in 1999 (NCDWQ, 1999b). Existing data were assembled from dischargers through the NPDES and pretreatment programs and ambient in-stream data on Clark Creek at Lincolnton. These data were analyzed to determine if toxic effluent resulted in violations of water quality standards in the creek. The analysis showed that current levels of cadmium, chromium, cyanide, lead, nickel and toluene in effluent are not likely to result in in-stream violations of standards.

Sand Dredging. Downstream of Rome Jones Road, two sand mining operations (Exhibit 2.2) use dragline dredges to extract sand from Clark Creek for use in building materials (Figure 2.4). When in active operation, these dredges increase turbidity--and potentially mobilize pollutants attached to clay and silt particles--in the local area and for some distance downstream.



Exhibit 2.2 Sand dredging area downstream of Rome Jones Road.
Irrigated turf farm in background.

**Table 2.3 Selected Monthly Average Discharge Concentrations City of Newton
WWTP, January 2000 through September 2001**

	Flow (MGD)	BOD₅ (mg/L)*	Total Residual Chlorine (mg/L)**	Ammonia-N (mg/L)***	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
Average, 21 months	3.4	0.6	0.274	0.2	17.3	1.36
Lowest monthly average	2.7	0.0	0.023	0.0	2.7	0.84
Highest monthly average	3.8	4.3	0.886	0.5	26.2	1.89
NPDES Permit Limit	5.0	15.0 summer 30.0 winter	None	6.0 summer 12.0 winter	None	None

* BOD₅ detection limit was 2.0 mg/L; values less than 2.0 were reported by the facility as 0.0.

** TRC detection limit was 0.050 mg/L; values less than 0.050 were reported by the facility as 0.0.

*** Ammonia-N detection limit was 0.10 mg/L; values less than 0.10 were reported by the facility as 0.0.

2.6.2 *Nonpoint Sources*

In the upper drainage, the full range of urban activities and pollution sources are of potential concern: roads, parking lots, rooftops, lawns, industrial areas, construction sites, etc. The list of pollutants which have been documented to increase with urbanization includes oils, antifreeze, tars, soaps, fertilizers, pesticides, solvents, and salts (e.g., Bales et al., 1999; Burton and Pitt, 2001).

Construction. Considerable commercial, institutional and residential development has occurred in the watershed over the past decade, especially in the I-40 corridor. Construction activities in numerous areas were ongoing during the course of the project. Major active construction sites during the study period are shown in Figure 2.4. Notable among those were the following:

- Widening of Tate Boulevard near the headwaters of Cline Creek.
- Numerous small commercial/light industrial sites east of Exit 128, north of I-40 in the Cline Creek drainage of Conover.
- Construction of the Hickory Civic Center west of Exit 126, between I-40 and US 70/321 draining to the mainstem Clark Creek.
- Shopping center construction east of Exit 126, south of I-40, draining to the mainstem Clark Creek.
- Expansion of the Catawba County Human Resources complex on Miller Branch in Hickory.

Erosion and sediment control measures are commonly observed at construction sites throughout the watershed. While these structures and practices, where appropriately constructed and maintained, can significantly reduce the amount of sediment that would otherwise reach nearby streams, actual practices are often not adequate to prevent stream impacts. During this project, the most extensive sediment impacts were observed in Miller Branch (Exhibit 2.3), which was impacted by the expansion of the Catawba County Human Resources complex (Exhibit 2.4). The construction project was not cited by the Division of Land Resources as being out of compliance with any applicable regulations.



Exhibit 2.3 Miller Branch
Showing sand and gravel deposition



Exhibit 2.4 Miller Branch near Catawba County
Human Resources complex construction

Industrial Stormwater. Forty-one industrial facilities have active stormwater permits in the study area, all but one operating under general permits (Table 2.4 and Figure 2.4). Eighty percent of these are in the upper drainage. The Cline Creek drainage has 16 such facilities, upper Clark Creek itself (above Miller Branch) has 13, while all other tributaries have four or fewer. Furniture manufacturing (15) is the most frequent industry classification. Machinery and fabricated metal products (6), textile mill products (5), and vehicle maintenance and petroleum storage (5) were also common.

Though the impervious areas associated with these facilities can be considerable, BMPs to control the quantity and timing of stormwater are not required in this watershed, and few facilities have implemented such practices. The general stormwater permits under which most of these facilities operate provide some measure of water quality protection, but do not require water quantity controls.

Two large industrial sites in the upper drainage deserve mention (Figure 2.1): a Martin Marietta stone quarry and a General Electric plant. The quarry is located adjacent to Clark Creek near Exit 126 off I-40 and covers approximately 300 acres. It has been in compliance with its NPDES stormwater permit. The General Electric plant, located on a tributary to Cline Creek, is not in current operation, but groundwater and surface water near the site have been monitored for volatile organic chemicals since 1983. Organic pollutants have been detected in small tributaries near the facility (see Section 5), but not further downstream in Clark Creek or Cline Creek.

Commercial and Residential Stormwater. Commercial and residential areas constitute 26% of the study area, a proportion which is similar in both the upper and lower watershed. As is the case with industrial areas, stormwater BMPs are not required for newly constructed commercial development or residential subdivisions. Stormwater ponds, infiltration areas and other practices are rarely observed in existing housing developments, warehouses, shopping centers and other developed areas with large expanses of impervious surface. Most of these areas, especially in the upper watershed and the Town Creek drainage in the lower study area, are served by storm sewers. Given the overall level of imperviousness in the upper watershed, hydrologic impacts on Clark Creek and its tributaries are likely, as are increased inputs of stormborne pollutants.

Table 2.4 Facilities with NPDES Stormwater Permits - Clark Creek Study Area

General Stormwater Permits		
<u>Permit No.</u>	<u>Facility</u>	<u>Stream</u>
NCG070063	Hairfield Vault Company; Inc.	Bills Branch
NCG050163	R. R. Donnelley Printing Co.	Smyre Creek
NCG180213	Lee Industries; Inc.	a UT of Smyre Creek
NCG080504	NC Army National Guard-Newton NG Armory	Clark Creek
NCG060158	Midstate Mills; Inc.	Town Creek
NCG170121	Carolina Mills; Inc.-Plant 4N	McLin Creek/ Town Creek
NCG170120	Carolina Mills; Inc.-Plant 3	Town Creek
NCG020514	Huffman Borrow Pit No. 1	UT Clark Creek
NCG170119	Carolina Mills; Inc.-Plant 2	Town Creek
NCG180060	Pinnacle Furniture Company; Inc.	Newton MSSS to Hildebran Creek
NCG180016	Lee Industries; Inc.	Hildebran Creek
NCG030394	Commercial Fabricators Inc-Catawba	Ut Cline Creek
NCG170024	Joan Fabrics Corp.- Newton Plant	Cline Creek
NCG080051	T.S.J.D.; Trucking Company; Inc.	UT To Cline Creek
NCG080399	Grand; LLC-City Of Hickory	Ut Clark Creek
NCG080117	Roadway Services (Spartan-Conover)	Cline Creek
NCG180017	C. R. Laine Furniture Co.; Inc.	Clark Creek
NCG180049	Lexington Furniture Industries	a UT of Clark Creek
NCG080628	Con-way Southern Express-NHN	UT Cline Creek
NCG170028	Fab Industries-Travis Knits	Clark Creek
NCG210147	Conweb Fibers; Inc.	Cline Creek
NCG030018	General Electric Company	UT To Cline Creek
NCG050178	Foamex L. P. - 4th Street Place SW	City Of Conover SS To Cline Creek
NCG180046	Lexington Furniture Industries	a UT of Clark Creek
NCG090002	Premium Coatings; Inc.	Cline Creek
NCG030246	Siecor Cable -Telecommunication	UT To Clark Creek
NCG020085	Martin Marietta	Clark Creek
NCG180023	Craftwork Guild	a UT of Cline Creek
NCG180085	Craftwork Frame Plant	Cline Creek
NCG180073	Classic Leather Inc.	a UT of Cline Creek
NCG180087	Lane Company; Inc.-Plant 14	Cline Creek
NCG180012	Vangaurd Furniture Co.; Inc.	a UT of Cline Creek
NCG180061	Lane Company-Laneventure Plt 10	Cline Creek
NCG180055	Clayton Marcus Co. Inc.	Hickory MSSS to Miller Branch
NCG160070	APAC-Carolina Inc.-Catawba	Clarks Creek
NCG160018	Carolina Paving of Hickory; Inc.	Hickory MSSS to Clark Creek
NCG030243	Siecor Corp. -Spectator Cable	UT To Clark Creek
NCG030164	Hickory Springs Manufacturing Company	Miller Branch
NCG180086	Hickory White	Clark Creek
NCG180177	Hickory Chair Co.-Div. of Lane Co.	a UT of Clark Creek
Individual Stormwater Permits		
<u>Permit No.</u>	<u>Facility</u>	<u>Stream</u>
NCS000029	Hickory Springs Manft. Co	Cline Creek

Agriculture. Agriculture is still an important activity in the lower study area, where cropland comprised a quarter of the land use in 1998. Conservation practices such as field borders and low tillage approaches are commonly used. While past agricultural practices resulted in large sediment inputs in this watershed, cultivated areas do not appear to be a major source of sediment at this time.

Other nonpoint sources. Almost the entire upper drainage area is served by municipal sanitary sewers. Throughout much of their length, Clark Creek and its tributaries are paralleled by sewer rights-of-way. Spills of raw sewage can occur due to blockage of these sewer lines or overflows due to stormwater infiltration or mechanical malfunction. For the 20-month period from January 2000 through August 2001, there were 21 spills within the study area reported to DWQ by local governments (Table 2.5). These spills ranged in volume from 350 to 57,000 gallons of untreated sewage. On average 15,000 gallons of waste per incident reached Clark Creek or one of its tributaries. Thirteen of the spills occurred in Newton's Hildebran Creek and Town Creek drainages.

**Table 2.5 Spills of Sewage to Clark Creek and Tributaries
January 2000 through August 2001**

Date	Receiving Stream	Volume (gallons)	Cause
1/13/00	Town	4,000	Roots
2/9/00	Clark	38,000	Grease
2/24/00	Clark	1,000	Grease, paper
3/20/00	Clark	50,000	Rain
3/28/00	Town	2,000	Roots
4/16/00	Clark	12,000	Rain
4/16/00	Hildebran	8,000	Rain
7/10/00	Hildebran	350	Debris
7/11/00	Clark	2,000	Rain
7/12/00	Clark	2,000	Rain
7/13/00	Hildebran	53,000	Deterioration
7/15/00	Clark	57,000	Roots, debris
9/6/00	Hildebran	3,000	Debris
10/9/00	Town	7,000	Debris
1/29/01	Town	500	Grease
2/21/01	Hildebran	9,000	Valve failure
3/12/01	Clark	500	Roots
4/18/01	Town	500	Debris
4/19/01	Hildebran	50,000	Roots
7/3/01	Hildebran	500	Debris
8/29/01	Hildebran	10,000	Roots
Total Volume		310,000 gallons	

2.6.3 Historical Issues

Like a number of other piedmont streams, Clark Creek and its major tributaries have been subject to sediment inputs and direct channel modification for over 100 years (see the Background Note “Landscape History and Channel Alteration in the Piedmont Region”). Erosion due to clearing of the uplands for agriculture was so pervasive in the late 1800s and early 1900s that sediment inputs raised the level of the streambed. This promoted frequent flooding and exacerbated drainage problems in the bottomlands, making cultivation of these fertile areas difficult. It is likely that this sedimentation had a major impact on stream habitat and aquatic life.

Sedimentation from the upland clearing that occurred during the 19th century was one of the major reasons for the dredging and channelization of stream that began in 1909. By drastically modifying the stream morphology, this channel modification has had a negative effect on stream habitat that still persists today. The indirect effects of channelization can be considerable and are discussed in Section 6.

2.7 Trends in Land Use and Development

While land use in the watershed has historically been dominated by agriculture, residential, commercial and industrial development have been increasingly important since World War II. Cropland acreage in Catawba County fell from 51,000 acres in 1969 to 20,000 in 1992 (Catawba County, 1999). The population of the county, meanwhile, increased substantially during this period. It has continued to do so, growing by 20% between 1990 and 2000 to a total of almost 142,000 (US Bureau of the Census data, available at <http://204.211.226.33/demographics/>).

The I-40 corridor has experienced particularly rapid development of commercial and light industrial facilities in recent years, and that trend is expected to continue into the foreseeable future. Residential development, both high density (apartment/condominium) and low density, will also expand to occupy land which is now in pasture, forestland and cropland, with growth in the lower study area occurring more slowly than in the northern portion.

2.8 Regulatory Issues and Local Water Quality Activities

Local ordinances. Catawba County has an ordinance regulating floodplain development, but local governments in the study area have no stormwater or riparian buffer requirements. The City of Newton has a delegated Erosion and Sedimentation Control Program. Construction erosion and sediment control in other portions of the study area are handled by the NC Division of Land Resources.

Background Note: Landscape History and Channel Alteration in the Piedmont Region

The condition of stream channels today depends not only on current watershed activities, but on historical land uses and management activities as well. The landscape of North Carolina's Piedmont region, like much of the southern Piedmont, has been substantially altered over the past 200 years. These changes have had major impacts on past stream conditions and continue to affect how channel networks today react to ongoing watershed activities. While circumstances vary from one place to another, the basic outline of these historical changes is widely accepted (see Ferguson, 1997; Wilson, 1983; Jacobson and Coleman, 1986; Simmons, 1993; Richter et al., 1995).

- Following widespread clearing of forests in the 19th century and subsequent intensive agricultural land use, extensive erosion of upland areas occurred throughout the southern Piedmont region. Conservation practices were virtually unknown prior to the 1930s (Trimble, 1974; Healy, 1985).
- The extent of cleared land peaked in the late 19th and early 20th centuries. For a variety of reasons, the amount of cultivated land in many parts of the Piedmont began to decline in the 1920s and 1930s, a trend that continues today. Much of this former cropland reverted to forest.
- With the advent of the soil conservation movement in the 1930s, tillage practices began to improve on the remaining cropland.
- During the period of most intensive agricultural activity, sediment filled many stream channels. The floodplains and lowland riparian corridors of many 3rd order and larger streams often aggraded (increased in elevation) by several feet to several meters in height due to the large volume of eroded soil transported from upland areas (e.g., see Wilson, 1983; Ferguson, 1997).
- Once upland erosion declined, streams began the process of removing the accumulated sediment. High sediment loads persisted for many years following the reduction in upland erosion as streams reworked the sediment stored on hill slopes and floodplains and within stream channels. (Meade, 1982; Meade and Trimble, 1974).
- In many rural areas streams have substantially recovered from this sedimentation. They have restabilized and may now support healthy populations of fish and macroinvertebrates. These streams have not necessarily returned to their former condition, however, but often remain incised and retain a more sandy appearance than previously. In other rural areas the process of recovery still continues.

In addition to the stresses imposed by historic agricultural impacts, many streams have also been channelized (straightened, deepened or realigned) to reduce flooding or to maximize the land available for farming. Channelization often induces substantial sedimentation due to subsequent stream downcutting and widening. In some cases entire channel networks, which had previously filled with sediment, were channelized and remain unstable decades later.

Many of these watersheds have since undergone, or are currently experiencing, significant development as the Piedmont continues to grow. The major hydrologic changes that accompany development and the resulting physical and biological deterioration of stream channels are well known. The impact of urbanization is often made worse, however, by the persistent effects of historical practices. Many streams are already incised and subject to ongoing bank erosion and sedimentation due to prior impacts from agricultural erosion and channel modification, leaving them extremely vulnerable to the altered hydrology brought on by urban and suburban growth. In highly impacted watersheds, the relative effects of these various disturbances can be difficult if not impossible to distinguish. It is clear, however, that the legacy of past land use practices is still with us, and that we cannot understand the current condition of many impaired streams without understanding the history of their watersheds.

State stormwater regulations. Until recently, the Clark Creek watershed did not fall under any state stormwater regulations. However EPA has developed a Phase II stormwater program, mandating that small communities not previously subject to federal stormwater requirements apply for permit coverage. Communities in urbanized areas designated by the US Bureau of the Census must apply for stormwater permit coverage by March 2003. Hickory, Conover, Newton and Catawba County meet these criteria. The federal regulations discuss development and implementation of comprehensive stormwater management programs including six minimum

measures: 1) public education and outreach on stormwater impacts; 2) public involvement/participation; 3) illicit discharge detection and elimination; 4) construction site stormwater runoff control; 5) post-construction stormwater management for new development and redevelopment; and 6) pollution prevention/good housekeeping for municipal operations. The regulations also require state permitting authorities to implement designation criteria that would be applied to communities outside of federally designated urbanized areas. Communities meeting these criteria can also be brought into the Phase II program. State regulations to implement the Phase II stormwater program are currently under development.

Catawba River Basin Buffer Rules. In 2000 the North Carolina Environmental Management Commission passed temporary rules requiring the maintenance of vegetated buffers along the mainstem of the Catawba River and mainstem lakes. These provisions do not apply to the Clark Creek watershed. Discussions regarding the development of a permanent rule have been initiated. The status of the permanent rule, including potential provisions and whether it may apply to the Clark Creek watershed, has not yet been determined.

TMDLs. DWQ is developing a TMDL (total maximum daily load) strategy for fecal coliform for the entire Clark Creek watershed. A copper TMDL will be developed in the future after additional data are collected and evaluated.

Citizen Initiatives. Local and regional citizen groups have expressed concern about water quality problems in Clark Creek and the South Fork Catawba River for a number of years. Many of the concerns relate to municipal and industrial wastewater discharges both within and downstream of the study area.

The Catawba River Foundation and the Catawba Riverkeeper developed a Catawba River Platform consisting of nine items believed to be critical to achieving an effective basinwide plan to protect the natural resources of the region. Over 43 organizations and individuals co-sponsored the platform, which included recommendations on stream buffers, sediment control, WWTP nutrient limits and other issues.

Other Concerns. Eutrophic conditions in Lake Wylie and several of its major tributaries have been evident for a number of years. To address eutrophication in Lake Wylie, DWQ and the South Carolina DHEC developed a point and nonpoint nutrient control strategy for the Lake Wylie watershed. Under this plan the Newton WWTP would be required to meet nutrient reduction limits upon expansion. For further information on the strategy, see the current Catawba River Basinwide Water Quality Management Plan (NCDWQ, 1999a).

Section 3

Potential Causes of Biological Impairment

The study identified those factors that were plausible causes of biological impairment in the Clark Creek watershed using both biological assessment and watershed-based approaches. An evaluation of benthic community data and other biological and habitat indicators can point toward general types of impacts that may likely impact aquatic biota. These stressors were flagged for further investigation. Land uses and activities in the Clark Creek watershed were also examined to identify potential stressors for further evaluation.

3.1 Key Stressors to be Evaluated in the Clark Creek Watershed

The following were evaluated as the most plausible candidate causes of impairment in Clark Creek.

1. Habitat Degradation. Initial reconnaissance indicated that much of the mainstem of Clark Creek and its larger tributaries could be characterized as follows:

- Banks are severely eroding (Exhibit 3.1).
- Bottom substrate consists almost entirely of unstable, shifting sand (Exhibit 3.2).
- Channel is mostly straight, with few bends.
- Water depth is mostly uniform—few pools and riffles.

These characteristics create an inhospitable environment for aquatic invertebrates and fish, even if water quality factors are favorable. A shifting sandy bottom is a suitable habitat for only a few types of aquatic organisms; the abundance and variety of organisms is generally higher in streams with a mix of rocks, wood, leaves and roots on the stream bottom. Similarly, a variety of depths and current velocities in the stream provides habitat for more kinds of aquatic life than the straight, shallow waters typical of Clark Creek.

2. Low Dissolved Oxygen. An initial evaluation of benthic community structure did not indicate the likely impact of low dissolved oxygen. However, given the presence of a major wastewater discharge, the potential impacts of oxygen consuming wastes were evaluated. Wastewater flows can make up a substantial proportion of the total streamflow, especially during dry weather. The scarcity of riffles could also be a concern, possibly limiting reaeration in the stream.

3. Toxic chemicals. Especially in the upper portion of the study area--48% of which is developed, including substantial drainage from industrial areas--there is a significant potential for a wide variety of toxicants to enter streams during rain events or site-specific mishaps (see Section 2.6). These include metals, pesticides and a range of other organic chemicals. Agricultural chemicals, including herbicides and insecticides, are potential contaminants in the lower watershed. Newton's wastewater discharge is also a potential source of toxicants, although the facility has been consistently passing effluent toxicity tests. Because of the wide range of potential toxicants and source activities in this watershed, toxicity merited further evaluation as a potential cause of impairment.

4. *Nutrients*. An initial review of macroinvertebrate data indicated that nutrients were not a likely cause of impairment, but further evaluation was conducted due to the presence of the wastewater discharge. Even if nutrients are not a likely source of stream impairment in this watershed, nutrient inputs from all watersheds in the South Fork Catawba drainage are important, given current eutrophication concerns in Lake Wylie and in the Catawba River in South Carolina. Nutrient concentrations in Clark Creek were monitored to provide additional background data for nutrient reduction efforts.



Exhibit 3.1 Severe bank erosion typical of Clark Creek



Exhibit 3.2 Unstable sand bed

Section 4

Biological Conditions and Stream Habitat

Biological assessment (bioassessment) involves the collection of stream organisms and the evaluation of community diversity and composition to assess water quality and ecological conditions. Evaluation of habitat conditions at sampling locations is an important component of bioassessment.

Prior to this study, DWQ's Biological Assessment Unit collected benthic macroinvertebrate samples from Clark Creek at several sites in the study area. The macroinvertebrate community in Clark Creek at SR 2012, near the downstream end of the study area, was rated Good-Fair (not impaired) in 1984 and Fair in 1990. Further upstream at SR 1149, above the Newton discharge, Clark Creek benthos were rated Good-Fair in 1984 and 1992. In 1984, Cline Creek at SR 1164 was rated Fair; it was receiving treated wastewater from Conover's Southwest WWTP at that time.

DWQ has not collected fish community data in the study area or at any location on the Clark Creek mainstem. The North Carolina Wildlife Resources Commission attempted to sample fish in Clark Creek near Maiden (exact location is unclear) in 1963. No fish were found and the stream was described as "highly polluted" (Louder, 1964).

Additional benthic community sampling was conducted during the present study to serve several purposes:

- To account for any changes in biological condition since the watershed was last sampled.
- To obtain more specific information on the actual spatial extent of impairment.
- To better understand which portions of the watershed may be contributing to biological impairment and which areas are in good ecological condition.
- To collect additional information to support a biologically driven identification of likely stressors.

This section describes the approach to bioassessment used during the study and summarizes the results of this work. Photographs of the sampling sites and a more detailed analysis of the condition of aquatic macroinvertebrate communities in the Clark Creek watershed may be found in Appendix A.

4.1 Approach to Biological and Habitat Assessment

Biologists surveyed macroinvertebrate communities and aquatic habitat at five locations on the mainstem of Clark Creek, two locations on tributary streams and two locations on reference streams outside of the study area (Figure 4.1). Sites are described in Section 4.2. The reference streams do not necessarily represent undisturbed conditions, but serve as comparison sites in less impacted watersheds within the same ecoregion and general geology as Clark Creek. The sampling was done in July and August 2000 and in April 2001.

Ideally sites would be located both upstream and downstream of all major sources of potential stress to aquatic organisms, such as construction along I-40, urbanization in Hickory, Conover and Newton, the Martin Marietta quarry, agricultural areas in the lower study area, the Newton WWTP, and sand mining operations. This was not feasible due to the widespread nature of potential nonpoint source inputs. It was not possible to sample upstream of all urban nonpoint sources, since the headwaters are within the city limits of Hickory. Also, a suitable sampling site was not found downstream of the sand mining operations below Rome Jones Road.

4.1.1 Benthic Community Sampling and Rating Methods

Macroinvertebrate sampling was carried out using the general procedures outlined in the Division's standard operating procedures (NCDWQ, 2001b). Reaches approximately 100 meters (328 feet) long were targeted, although the actual stream length sampled varied with site conditions. Standard qualitative sampling was used for most sites. This method included ten samples: two kick-net samples, three bank sweeps, two rock or log washes, one sand sample, one leaf pack sample, and visual collections from large rocks and logs. At smaller stream sites, the abbreviated Qual 4 and Qual 5 methods were used. The Qual 4, which has been used by DWQ to sample small streams for some time, involved four samples: one kick, one sweep, one leaf pack and visual collections. The Qual 5 was similar to the Qual 4 but also includes a rock or log wash. Use of the Qual 5 was initiated part way through the study to allow for a better characterization of the midge population than is possible using the Qual 4. Organisms were identified to genus and/or species.

Two primary indicators or metrics are derived from macroinvertebrate community data: the diversity of a more sensitive subset of the invertebrate fauna is evaluated using EPT taxa richness counts; and the pollution tolerance of those organisms present is evaluated using a biotic index (BI). "EPT" is an abbreviation for Ephemeroptera + Plecoptera + Trichoptera (mayflies, stoneflies and caddisflies), insect groups that are generally intolerant of many kinds of pollution. Generally, the higher the EPT number, the more healthy the benthic community. A low biotic index value indicates a community dominated by taxa that are relatively sensitive to pollution and other disturbances (intolerant). Thus, the lower the BI number, the more healthy the benthic community.

Biotic index values are combined with EPT taxa richness ratings to produce a final bioclassification (Excellent, Good, Good-Fair, Fair or Poor). Final bioclassifications are used to determine if a stream is impaired. Streams with bioclassifications of Excellent, Good, and Good-Fair are all considered unimpaired. Those with Fair and Poor ratings are considered impaired. *Under current DWQ policy, streams under four meters in width are generally not formally rated but are evaluated qualitatively based on professional judgment.* Small streams sampled using the Qual 4 method that have scores consistent with a Good-Fair or better rating are labeled as 'not impaired'. An adequate database has not yet been assembled to allow formal ratings to be applied to streams sampled using the Qual 5 method. These sites are evaluated based on professional judgement.

4.1.2 *Habitat Assessment Methods*

At the time benthic community sampling was carried out, stream habitat and riparian area conditions were evaluated for each reach using DWQ's standard habitat assessment protocol for piedmont streams (NCDWQ, 2001b). This protocol rates the aquatic habitat of the sampled reach by adding the scores of a suite of local (reach scale) habitat factors relevant to fish and/or macroinvertebrates. Total scores range from zero (worst) to 100 (best). Individual factors include (maximum factor score in parenthesis):

- channel modification (5);
- in-stream habitat variety and area available for colonization (20);
- bottom substrate type and embeddedness (15);
- pool variety and frequency (10);
- riffle frequency and size (16);
- bank stability and vegetation (14);
- light penetration/canopy coverage (10); and
- riparian zone width and integrity (10).

4.2 Findings

4.2.1 *Description*

Selected habitat and biological characteristics for each site sampled during the study are shown in Table 4.1, which also includes information on historical sites not sampled during this investigation. Some streams were too small to be given a formal rating (bioclassification). A narrative summary of conditions at each current site follows. See Appendix A for additional details.

Clark Creek Mainstem:

- *Clark Creek at 16th Street* (near 16th St. SE, south of Fairbrook Optimist Park, Hickory). This site was chosen for its favorable riffle habitat and its location upstream of the Martin-Marietta quarry and major construction projects near I-40. While too small to rate, Clark Creek was clearly highly impacted at this upstream location. Benthos were sparse and some taxonomic indicators of toxicity were common. Habitat was good, with a variety of bedrock, boulder, cobble, gravel, sand and organic substrates. Riffles were frequent and bank erosion was slight to moderate.
- *Clark Creek at Sweetwater Road* (21st St. Drive SE, south of I-40, Hickory). This location was chosen because it was downstream of the quarry and major construction projects near I-40. This location was too small for a formal rating, but clearly supported only a highly degraded benthic population dominated by tolerant organisms. Substrate was mostly sand. Other characteristics included: a few riffles; shallow pools; high, riprapped banks; moderate erosion.
- *Clark Creek at 20th Avenue* (near the Hickory compost facility, south of the intersection of US 70/321 and Fairgrove Rd.). This site was chosen because of its location downstream of the confluence with Miller Branch and the densely developed I-40 and US 70/321 corridors. This site had a more diverse benthic population than the upstream sites, but was still

impaired, receiving a Fair rating. Substrate was mostly sand. Other characteristics included: no riffles; shallow pools; high, steep banks; moderate to severe erosion.

- *Clark Creek at SR 1149* (Old Conover-Startown Rd., Newton; upstream of bridge). This site had been sampled in previous years and was chosen as a location upstream of the Newton WWTP. This station was sampled twice during the study, receiving a rating of Fair on the first occasion and Good-Fair on the second. Though the benthic community was degraded here, both EPT richness and BI values were improved over the 20th Avenue location. Substrate was mostly sand. Other characteristics included: no riffles; shallow pools; high, steep banks; moderate erosion.
- *Clark Creek at SR 2012* (Rome Jones Rd., upstream of bridge). This site had been sampled in previous years and was chosen as a location downstream of the Newton WWTP. Located near the bottom of the study area, this site received a Fair rating, as it did when last sampled in 1990. Overall, the benthic community was similar to the SR 1149 site. Substrate was mostly sand. Other characteristics included: no riffles or pools; high, steep banks; moderate to severe erosion.

Tributaries:

- *Town Creek at Southside Park* (off US Bus. 321, Newton). Town Creek is a major tributary and has substantial developed and agricultural land uses upstream. This site was rated Good-Fair. Though clearly impacted, it would not be considered impaired. Substrate was primarily sand, with some cobble. Sticks, logs and leaves were common and riffles were present. Banks were high and steep, erosion moderate to severe.
- *Cline Creek at SR 1164* (Old St. Paul's Church Rd., Newton). Cline Creek is a major tributary sampled in previous years. The creek was too small to rate, but its numerical scores were even better than Town Creek. Though clearly impacted, it would not be considered impaired. Comparison of the July 2000 results with past surveys indicated a definite improvement. Substrate was primarily sand. Sticks, logs and leaves were abundant. Riffles were infrequent though present. Banks were high and steep, erosion moderate to severe.

Reference Streams:

- *Carpenter Creek at US 321* (near SR 1338, Lincolnton). This site was chosen because of the limited amount of urbanization in its watershed. Previous sampling at Carpenter Creek also allowed for historical comparisons. This site was sampled using the Qual 5 method and could not be rated, but supported a diverse benthic community for a small stream, though some decline was apparent compared to past surveys. Substrate had a good variety of boulders, cobble, gravel, sand and organic substrates. Other characteristics included: frequent riffles; some pools; banks only moderately steep and high; low to moderate erosion. (Carpenter Creek, shown on Figure 1.1, is outside the study area and does not appear on Figure 4.1.)
- *Pinch Gut Creek at SR 2007* (West Maiden Rd., Maiden). This site was also chosen because of the limited urbanization in its drainage. It received a bioclassification of Good. Substrate was primarily sand. Other characteristics included: abundant sticks, logs and leaves; some riffles and pools; banks steep; erosion moderate.

4.2.2 Summary of Conditions and Nature of Impairment

Habitat throughout the study area was relatively poor at most sites, and was characterized by a lack of riffles and pools, unstable substrate and banks, and limited microhabitat. The stream bottom contained a high percentage of sand at most sampling locations; only the locations at 16th Street (furthest upstream) on the mainstem and Carpenter Creek (a reference location) were estimated at less than 60% sand. On the mainstem of Clark Creek in particular, sand is ubiquitous, filling pools, and covering riffles and other bottom structure. Sand deposits can exceed four feet in depth. Deadfall trees create the only eddies and pools; stream reaches without fallen trees typically consist of a few inches of clear water flowing over a flat sand bottom.

The results of the current surveys indicated that the benthic communities of Clark Creek are likely impaired for the entire length of the study area and are generally in Fair condition, though findings at the SR 1149 site may indicate temporal variability in the benthic community. EPT diversity is generally low and BI values indicate the presence of many organisms adapted to diverse stresses. The composition of the benthic community provides no indication that organic enrichment is a major concern in the study area. Community composition indicates likely toxic impacts at the uppermost mainstem site, above I-40. Benthic communities in Cline and Town Creeks, while clearly degraded, would not be considered impaired. Benthos were not sampled in other tributaries within the study area.

There is some evidence that biological condition in the mainstem has declined since the 1980s. Clark Creek at SR 2012 received a Good-Fair rating in 1984, declined to Fair in 1990, and remains Fair. Clark Creek at SR 1149 was Good-Fair in 1984 and 1992 and received ratings of Fair and Good-Fair during two sampling events conducted in 2000 and 2001. Cline Creek appears to have improved since 1984, possibly due to the removal of a domestic wastewater discharge.

Table 4.1 Selected Benthic Community and Habitat Characteristics¹, Clark Creek Study Sites

Location	Date	Stream Width (m) ²	Avg. Depth (m)	Substrate: % sand and silt ³	Habitat Score (max. of 100) ⁴	EPT ⁵ Taxa Richness	EPT ⁵ Biotic Index	Bioclassification ⁵
Clark Ck. at 16 th St.	4/17/01	2.5	0.1	45	70	7	5.7	Not rated*
Clark Ck. at Sweetwater Rd.	7/18/00	3	0.1	75	40	8	6.49	Not rated*
Clark Ck. at 20 th Ave.	4/17/01	3	0.2	70	44	2	6.58	Not rated**
Clark Ck. at SR 1149	8/14/00	4	0.1	80	52	10	6.02	Fair
	9/84					16	5.81	Good-Fair
	8/92					16	5.74	Good-Fair
	7/26/00	6	0.4	90	54	13	5.59	Fair
	4/17/01	7	0.2	95	39	15	4.61	Good-Fair
Clark Ck. at SR 2014	6/84					16	5.80	Good-Fair
	9/84					15	6.17	Fair
	9/90					13	6.46	Fair
Clark Ck. at SR 2012	6/84					14	5.81	Good-Fair
	9/84					19	6.26	Good-Fair
	9/90					6	5.33	Fair
	7/26/00	7	0.4	90	40	13	5.64	Fair
Cline Ck. at SR 1164	9/84						6.21	Fair
	7/26/00	3	0.3	70	53	16	5.22	Not Impaired (at least Good-Fair)*
Town Ck. at US 321	8/14/00	4	0.2	80	58	14	5.41	Good-Fair
Carpenter Ck. at US 321	9/84						4.61	Excellent
	6/94						3.90	Good
	4/17/01	3	0.1	50	72	20	4.44	Not Rated**
Pinch Gut Ck. at SR 2007	4/17/01	4	0.4	85	56	22	4.31	Good

1. Habitat data available for 2000 and 2001 samples only.

2. Wetted channel width at time of sampling.

3. Based on visual estimate of substrate size distribution.

4. See text for list of component factors.

5. See text for description.

* Qual 4 method. See text for discussion.

** Qual 5 method. See text for discussion.

Section 5

Chemical and Toxicological Conditions

Water quality assessment provides information to evaluate whether chemical and physical conditions negatively affect benthic communities. Two broad purposes of this monitoring are:

1. To characterize water quality conditions in the watershed; and
2. To collect a range of chemical, physical and toxicity data to help evaluate the specific causes of impairment and to identify the sources.

This section summarizes the sampling and data collection methods used and discusses key monitoring results. See Appendix B for a more detailed discussion of methodology and a more comprehensive presentation of results.

DWQ does not have an ambient station in the study area, although ambient data are collected from Clark Creek further downstream at Grove Street in Lincolnton (station #02143260). In-stream data are also collected by the Newton WWTP as a requirement of the facility's NPDES permit.

5.1 Approach to Chemical, Physical and Toxicity Sampling

5.1.1 General Approach

General Water Quality Characterization. The study area was divided into upper and lower sub watersheds, as discussed in Section 2. Two integrator stations, one located at the downstream end of each subwatershed, were sampled on a near monthly basis to characterize water quality conditions (see Section 5.12 for site locations). Samples were collected seven times between February and October 2001. A standard set of parameters similar to those evaluated at DWQ ambient stations was utilized (see Appendix B). Grab samples were collected during both baseflow and storm conditions. Baseflow periods were defined as those in which no measurable rain fell in the watershed during the 48-hour period preceding sampling. Storm samples were collected on the rising stage of the hydrograph. Fecal coliform samples were collected under baseflow conditions on five occasions between August 9 and September 8, 2000.

Stressor and Source Evaluation. Samples were collected at a variety of locations in order to identify major chemical/physical stressors to which aquatic biota were exposed, evaluate toxicity and assess major sources. Station locations for stressor identification sampling were linked closely to areas of known biological impairment (benthic macroinvertebrate sampling stations) and to specific watershed activities believed to represent potential sources of impairment. Both storm and baseflow samples were collected during a monitoring period extending from February to October 2001

Sampling focused primarily on those physical and chemical parameters that preliminary investigations indicated merited investigation as plausible causes of biological impairment. These included low dissolved oxygen, nutrients and toxicity from a variety of potential sources,

as discussed in Section 3. Because of the diverse land use in the Clark Creek watershed and the wide variety of activities that could potentially result in toxicity, storm event sampling included a wide range of pollutants, including the following:

- metals;
- chlorinated pesticides and PCBs (polychlorinated biphenyls; EPA Method 608);
- selected current use pesticides (GC/MS—gas chromatography/mass spectroscopy);
- PAHs (polycyclic aromatic hydrocarbons; EPA Method 610);
- phenols (EPA Method 604);
- semi-volatile organics (EPA Method 625);
- MBAS (methylene blue active substances, an indicator of anionic surfactants); and
- MTBE (methyl tert-butyl ether).

Ambient toxicity tests (bioassays) were conducted on samples collected at selected benthic macroinvertebrate sampling sites to evaluate whether toxic conditions were present at those locations. Multiple tests were conducted at each site evaluated. Laboratory bioassays provide a method of assessing the presence of toxicity from either single or multiple pollutants and can be useful for assessing the cumulative effect of multiple chemical stressors. Acute tests were conducted on storm samples, while chronic tests were conducted on samples collected during nonstorm periods. The following specific tests were used: ambient tests for acute toxicity using protocols defined as definitive in USEPA document EPA/600/4-90/027F (USEPA, 1993) using *Ceriodaphnia dubia* with a 48-hour exposure; ambient tests for chronic toxicity using the North Carolina *Ceriodaphnia* Chronic Effluent Toxicity Procedure (NC Division of Water Quality, 1998). All toxicity test samples were collected and transported in glass containers.

Field measurements (pH, dissolved oxygen, specific conductance standardized to 25 degrees C and temperature) were made on numerous occasions at locations throughout the watershed to further characterize water quality conditions and to investigate potential stressor source areas. Data sondes, multiparameter probes with a data logging capability, were deployed simultaneously for four days in August 2001 at four locations in the watershed. Dissolved oxygen (DO), pH, water temperature, and specific conductance were recorded on a quarter-hourly basis.

Water Quality Benchmarks. In order to help evaluate whether a significant likelihood existed that observed concentrations may have a negative impact on aquatic life, measured concentrations were compared to EPA's National Ambient Water Quality Criteria (NAWQC) for freshwater (USEPA, 1999) and Tier II benchmarks (USEPA, 1995). Metals benchmarks were adjusted for hardness where appropriate (USEPA, 1999). For chromium, the NAWQC for Cr VI was used. The use of NAWQC and other benchmarks is discussed in more detail in Appendix B.

Benchmarks were used for initial screening of potential impacts. Final evaluation of the likely potential for metals, and other analytes, to negatively impact aquatic biota considered all lines of evidence available, including toxicity bioassays and benthic macroinvertebrate data, in addition to data on analyte concentrations.

5.1.2 Site Selection

Primary sampling stations were chosen based on several criteria: accessibility, proximity to benthic sampling sites, proximity to key sources and source areas. These sites are listed below. Some were also sampled for benthic macroinvertebrates and have been described in Section 4 (see Figure 5.1 and Table 5.1).

- Clark Creek at SR 2007 (CLCL01). This site was located at the downstream end of the study area, west of Maiden, and served as the lower integrator station. Stressor identification sampling and toxicity sampling were also conducted at this site because of its location downstream of the Newton discharge.
- Clark Creek at Southside Park (CLCL02). Located off US 321 at the downstream end of the upper study area, this site served as the upper integrator station. Since this site captures the portion of Clark Creek draining the most urbanized part of the watershed, stressor identification sampling and toxicity sampling were also conducted here. Sampling was conducted for a wide range of potential toxicants (see Section 5.11).
- Clark Creek at SR 2012 (CLCL03). This station was located at Rome Jones Road, approximately 1.0 mile (1.6 km) downstream of the Newton WWTP discharge. Sampling focused primarily on evaluating potential toxicity issues associated with Newton's discharge. This was also a biological monitoring location.
- Clark Creek at 20th Ave. SE (CLCL06). This site was located near the Hickory compost facility, south of the intersection of US 70/321 and Fairgrove Road. It was located above the confluence of Clark Creek with Cline and Hildebran Creeks and captures drainage from the entire Hickory portion of Clark Creek. Monitoring at this location was limited primarily to measurement of field parameters. This site was also a biological monitoring location.
- Clark Creek at Sweetwater Rd. (CLCL07). Located in Hickory, 1.7 miles (2.7 km) above CLCL06, this site was downstream of major construction projects along I-40 and upstream of Miller Branch. Monitoring at this location was limited primarily to measurement of field parameters. This site was also a biological monitoring location.
- Clark Creek at Exit 126, I-40 (CLCL08). This site was located just downstream of the Martin Marietta quarry.
- Clark Creek at 16th Street (CLCL09). This site was located south of Fairbrook Optimist Park, Hickory and was chosen to evaluate conditions upstream of the Martin Marietta quarry and major construction projects near I-40. This was also a biological monitoring location.
- Cline Creek at SR 1164 (CLCN01). Located in the lower portion of the Cline Creek watershed, this site was sampled primarily to assess general water quality in this major tributary and to evaluate potential impacts from the abandoned General Electric manufacturing facility located approximately 1.8 miles (2.9 km) upstream. Monitoring at this location was primarily limited to measurement of field parameters. This was also a biological monitoring location.
- Hildebran Creek at NC 10 (CLHB01). This site drained a heavily developed largely residential section of Newton. Monitoring at this location was primarily limited to measurement of field parameters.
- Town Creek at US 321 (CLTS01). Located near Southside Park, this site was chosen to evaluate this large tributary that receives drainage from both developed and agricultural areas. Monitoring at this location was primarily limited to measurement of field parameters. This site was also a biological monitoring location.

Table 5.1 Summary of Monitoring Approaches Used at Primary Sampling Sites

	Station Code	Location	Monitoring Approach				
			Benthos	Water Quality ¹	Toxicity Bioassay	Data Sonde	Susp. Sed. ²
Upper Study Area	CLCL09	Clark Creek at 16 th St.	✓	✓			
	CLCL08	Clark Creek at Exit 126, I-40		✓			
	CLCL07	Clark Creek at Sweetwater Rd.	✓	✓		✓	✓
	CLCL06	Clark Creek at 20 th Ave. SE	✓	✓		✓	✓
	CLCL10	Clark Creek at SR 1149	✓				
	CLCN01	Cline Creek at SR 1164	✓	✓			✓
	CLHB01	Hildebran Creek at NC 10		✓			
	CLCL02	Clark Creek at Southside Park		✓ +	✓	✓	✓
Lower Study Area	CLTS01	Town Creek at US 321	✓	✓			✓
	CLCL03	Clark Creek at SR 2012	✓	✓	✓	✓	
	CLCL01	Clark Creek at SR 2007		✓ +	✓		
Reference							
	CLPG01	Pinch Gut Creek at SR 2007	✓				
	CLCA01	Carpenter Creek at US321	✓				

Note: For comprehensiveness this table includes both chemical/physical and benthic community sampling locations.

1. Includes sample collection and/or regular field measurements. Field parameters were also measured at all benthic community sites at the time samples were collected.
 2. Susp. Sed.--sampling station for SSC (suspended sediment concentration). See Appendix B for discussion.
- + Integrator station.

5.2 Water Quality Characterization

During the period between February and October 2001, five baseflow and two stormflow samples were collected at both integrator stations in order to provide a general picture of water quality in the study area. Selected results are shown in Table 5.2 and are presented in more detail in Appendix B. For comparative purposes, data (January 2000 – July 2001) from the ambient station (02143260) located on Clark Creek downstream of the study area at Grove Street in Lincoln County are also included in Table 5.2. Results at this location cannot be differentiated into baseflow and stormflow samples.

Table 5.2 Median Values of Selected Parameters at Integrator and Ambient Stations

Parameter	Clark Creek at SR 2007 CLCL01		Clark Creek at Southside Park CLCL02		Clark Creek at Grove St. #02143260
	BF	SF	BF	SF	+
Dissolved Oxygen (mg/L)	7.6	7.7	8.3	8.0	8.0
Specific Conduct. (μS/cm)	307	146	109	76	337
pH (s.u.)	7.3	7.1	7.3	6.7	7.5
TKN (mg/L)	0.8	1.4	0.6	1.2	0.5
Nitrate + Nitrite N (mg/L)	1.79	1.16	0.54	0.54	2.3
Ammonia N (mg/L)	0.2	0.1	0.1	0.5	0.13
Total Phosphorus (mg/L)	0.32	0.13	0.04	0.05	0.40
Turbidity (NTU)	13.9	225.8	5.9	153.3	9.5
Hardness as CaCO ₃ (mg/L)	66.0	40.8	41.0	28.0	56
Aluminum (μg/L)	250	690	107	888	800
Arsenic (μg/L)	< 5	< 5	< 5	< 5	< 10
Chromium (μg/L)	< 1	< 6	< 1	3	< 25
Copper (μg/L)	2	8	< 1	7	3.6
Lead (μg/L)	< 1	8	< 1	7	< 10
Manganese (μg/L)	72	226	68	160	93
Nickel (ug/L)	< 1	< 4	< 1	2	< 10
Zinc (μg/L)	5	29	3.2	31	13

Key: BF -- Baseflow; SF -- Stormflow

+ Ambient streamflow conditions; samples collected regardless of stream conditions.

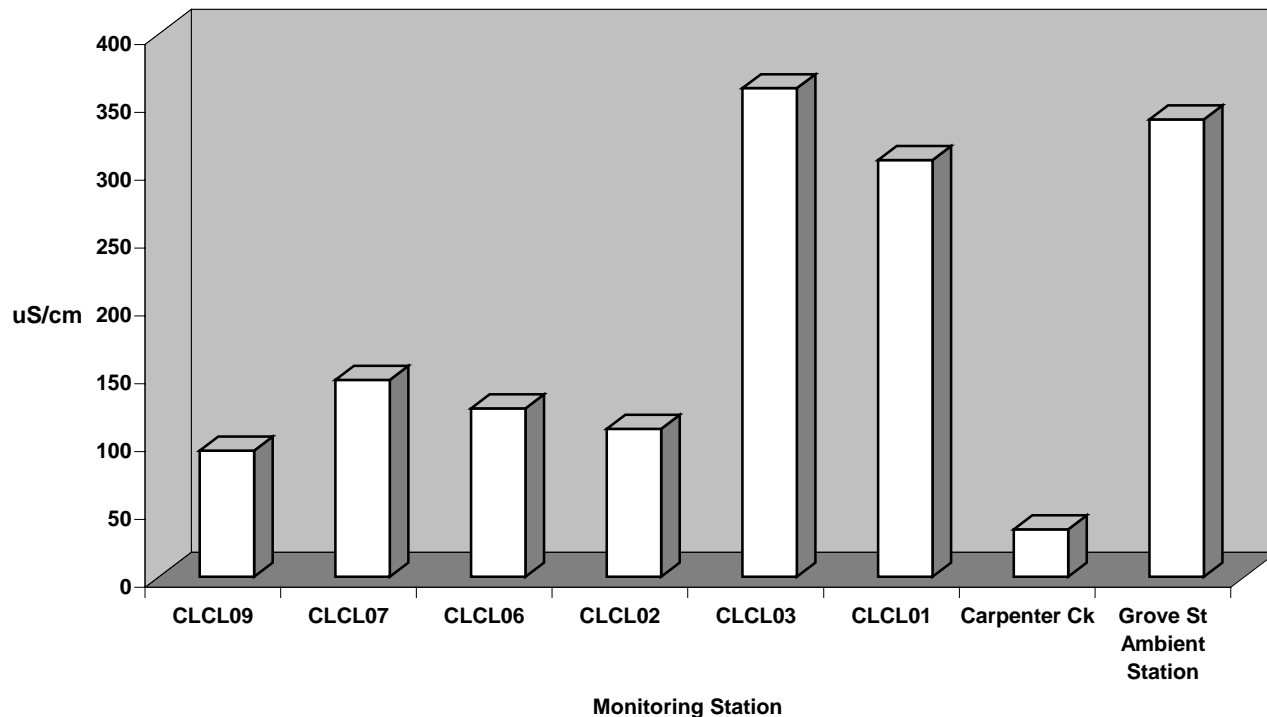
- Dissolved oxygen levels at both locations were typically adequate during both storm and baseflow conditions.
- Baseflow specific conductance values were elevated in the upper study area (CLCL02) but were particularly high (median of 331 μS/cm) in the lower study area (CLCL01). This reflects the influence of the Newton WWTP discharge. Specific conductance levels at the ambient station were also very high, likely due to several WWTP discharges in the lower watershed.
- Turbidity levels during storm conditions (median of 226 NTUs and 153 NTUs at CLCL01 and CLCL02, respectively) were indicative of the high levels of suspended sediment moving in the stream at these times.
- Nitrogen and phosphorus levels were elevated at both locations, but were especially high at CLCL01, below the Newton discharge. Baseflow nitrogen levels at the upper integrator stations (median TN of over 1.7 mg/L) were very high for a stream not receiving wastewater.
- High levels of a number of metals were observed. Metals concentrations will be discussed in Section 5.3.

An upstream-downstream profile of specific conductance (Figure 5.2) clearly illustrates differences between the upper and lower portions of the study area. Most mainstem locations above the Newton WWTP typically had median baseflow specific conductance values of around

100 $\mu\text{S}/\text{cm}$, although values are generally closer to 150 $\mu\text{S}/\text{cm}$ just below the Martin Marietta quarry (CLCL07). Values were highest at CLCL03, about one mile below the Newton WWTP outfall. Specific conductance levels in Carpenter Creek (median of 35 $\mu\text{S}/\text{cm}$; see Figure 5.2) were indicative of unimpacted waters in this area. Typical values in most tributaries of Clark Creek within the study area were similar to those in the upper mainstem. Median tributary values were as follows:

- Miller Branch-80 $\mu\text{S}/\text{cm}$
- Cline Creek-96 $\mu\text{S}/\text{cm}$
- Hildebran Creek-105 $\mu\text{S}/\text{cm}$
- Town Creek-106 $\mu\text{S}/\text{cm}$
- Bills Branch-124 $\mu\text{S}/\text{cm}$
- Betts Branch-91 $\mu\text{S}/\text{cm}$

Figure 5.2 Median Baseflow Specific Conductance at Selected Monitoring Stations



The geometric mean of five fecal coliform samples collected during baseflow conditions over a 30-day period in August and September 2000 exceeded the North Carolina standard for these waters, both above and below the wastewater discharge (Table 5.3). High fecal coliform levels do not appear to be due to sewage spills. Only one such spill (September 6, into Hildebran Creek) was reported between July 16 and September 8, 2001 (see Section 2).

Table 5.3 Fecal Coliform Monitoring Results (col/100ml)

Date (all 2000)	CLCL01 Clark Creek at SR 2007	CLCL02 Clark Creek at Southside Park
August 9	540	490
August 15	> 710	570
August 24	1200	560
August 29	730	860
September 8	520	560
Geometric Mean	705.4	596.2
NCWQS	200	

5.3 Stressor and Source Identification

5.3.1 Toxicity: Project Data

As discussed in Section 3, given the complexities of land use within the urban areas of Hickory, Conover and Newton, a wide range of potential toxicants could conceivably affect streams in the study area. Further downstream the Newton WWTP and agricultural areas are also potential sources of toxicants. To evaluate whether toxic conditions were present four ambient chronic (during baseflow) and two acute (during storm events) bioassays were conducted on samples collected at each of two locations, CLCL01 and CLCL02. Additionally, three chronic bioassays were conducted at CLCL03, 1 mile below the Newton WWTP outfall. Results of bioassay sampling are summarized in Table 5.4. Chemical sampling was conducted at several tributary stations, although no bioassays were performed.

This section discusses the results of bioassays and chemical analyses at mainstem sites, followed by a discussion of results for tributary locations.

Table 5.4 Bioassays Conducted in Clark Creek, 2001

Date (all 2001)	Clark Creek at SR 2007 (CLCL01)		Clark Creek at SR 2012 (CLCL03)		Clark Creek at Southside Park (CLCL02)	
	Chronic Bioassay	Acute Bioassay	Chronic Bioassay	Acute Bioassay	Chronic Bioassay	Acute Bioassay
March 21	-	pass	-	-	-	pass
April 17	pass	-	-	-	pass	-
May 17	pass	-	pass	-	pass	-
June 15	pass	-	pass	-	pass	-
June 27	-	pass	-	-	-	pass
October 9	pass	-	pass	-	pass	-

Clark Creek Mainstem. At both Clark Creek at Southside Park (CLCL02) and Clark Creek at SR 2007 (CLCL01), all four chronic (baseflow) bioassays and both acute (storm event) bioassays passed. These bioassays provided no indication of toxic conditions (see Appendix B, Table B.2 for additional information). On three of the occasions on which chronic bioassays were conducted at the above locations, chronic bioassays were also conducted at CLCL03, which is closer to the Newton WWTP than is CLCL01. All three of these bioassays also passed.

Chemical analyses conducted at CLCL01 and CLCL02 found few organic compounds (see Appendix B for additional information). Pentachlorophenol and 4-Nitrophenol were detected in a single baseflow sample at CLCL02. [Although these analytes were identified, concentrations could not be quantified by the laboratory. Target quantitation limits for the analytes were 0.05 ppb and 3.2 ppb, respectively.] Metolachlor, a commonly used pre-emergent herbicide, was detected in one of the two storm samples at both sites (1.18 µg/L at CLCL01 and 1.03 µg/L at CLCL02). No NAWQC or other benchmarks are available for metolachlor, but concentrations observed in Clark Creek are several orders of magnitude below effects levels reported in the literature (see discussion in Appendix B). Metolachlor is sold under brand names like Blazer and Lasso. No other pesticides or PCBs were detected during the assessment.

MBAS (surfactants) were detected in several baseflow samples at CLCL02. Concentrations (0.011 mg/L and 0.029 mg/L) are significantly lower than the North Carolina standard of 0.500 mg/L. MBAS were present at substantially higher levels (0.263 mg/L and 0.276 mg/L) at CLCL01, below the Newton WWTP, although these concentrations are still below the NC standard and bioassays did not indicate toxicity.

Trace metals were commonly found, often at total concentrations exceeding EPA's National Ambient Water Quality Criteria. Dissolved metals were not evaluated. Table 5.5 compares baseflow total metals concentrations to hardness-adjusted chronic benchmarks. Table 5.6 compares storm event total metals concentrations to acute benchmarks. Aluminum levels in excess of NAWQC were common at both CLCL01 and CLCL02 under baseflow and storm conditions. Lead, silver, copper and zinc exceedences were also observed.

Since total rather than dissolved metals concentrations were measured, the bioavailability of these substances is difficult to fully assess. Adjusting benchmarks for hardness only partially addresses this issue. Metals such as aluminum, iron, manganese, copper and zinc are widespread in North Carolina's waters. Potential effects on benthic macroinvertebrates are uncertain since organisms in a given locality may be adapted to local concentrations. The fact that ambient bioassays conducted on samples collected at the same time (within minutes) of chemical samples provided no evidence of toxicity is a strong indication that the concentrations of metals in the stream were not problematic.

Total residual chlorine (TRC) was measured on site on four occasions above and below the Newton WWTP outfall with a Hach DPD colorimeter (Table 5.7). Concentrations one mile downstream of the outfall ranged from 0.08 to 0.17 mg/L, all well above the NAWQC chronic screening value of 0.011 mg/L. Concentrations 2.5 miles below the outfall were much lower though still consistently above the screening value. Though sampling was conducted during baseflow, sampling times did not represent worst case (minimal dilution) streamflow conditions.

Table 5.5 Total Baseflow Metals Concentrations and NAWQC Chronic Values (µg/L)

Clark Creek at Southside Park (CLCL02)									
Parameter	2/19/2001	NAWQC Levels	4/17/2001	NAWQC Levels	5/17/2001	NAWQC Levels	6/15/2001	NAWQC Levels	10/9/2001
Hardness (mg/L)	40.0	--	40.0	--	42.0	--	41.0	--	48.5
Aluminum	251	87	146	87	88	87	107	87	103
Cadmium	-	1	-	1	-	1	-	1	-
Chromium	1	11	-	11	-	11	-	11	-
Copper	-	4	-	4	-	4	-	4	-
Iron	859	1000	442	1000	423	1000	380	1000	245
Lead	-	1	1	0.99	-	1	-	1	-
Manganese*	49	120	70	120	64	120	71	120	68
Nickel	-	24	-	24	-	25	-	25	-
Silver*	-	0.4	-	0.4	-	0.4	-	0.4	1.1
Zinc	-	55	3	55	1	57	3	56	4
Clark Creek at SR 2007 (CLCL01)									
Hardness (mg/L)	59.0	--	66.0	--	64.0	--	69.0	--	69.5
Aluminum	327	87	157	87	250	87	369	87	172
Cadmium	-	2	1.5	1.8	1.1	1.7	-	2	-
Chromium	-	11	-	11	-	11	-	11	-
Copper	-	6	2	7	2	6	4	7	4
Iron	814	1000	483	1000	593	1000	785	1000	340
Lead	1	2	-	2	-	2	-	2	-
Manganese*	56	120	77	120	72	120	109	120	61
Nickel	-	33	-	37	2	36	-	38	-
Silver*	-	0.4	-	0.4	-	0.4	-	0.4	-
Zinc	2	77	5	84	9	82	9	88	5

Values in bold type exceed the applicable screening benchmark.

* Ag and Mn chronic screening values are Tier II (USEPA, 1995); all others are NAWQC (USEPA, 1999). Cr VI NAWQC is used for chromium. See Appendix B for discussion.

- Metal concentration was below detection. Detection limits were less than or equal to screening values except for silver. See Appendix B for detection limits. Screening values were adjusted for hardness where appropriate.

Table 5.6 Total Stormflow Metals Concentrations and NAWQC Acute Values (µg/L)

Clark Creek at Southside Park (CLCL02)				Clark Creek at SR 2007 (CLCL01)		
Parameter	3/21/2001	NAWQC	6/27/2001	NAWQC	3/21/2001	NAWQC
Hardness (mg/L)	24.0	---	32.0	---	34.0	---
Aluminum	926	750	849	750	972	407
Cadmium	0.5	0.9	-	1	0.8	-
Chromium	4	16	2	16	6	-
Copper	9	4	4	5	11	5
Iron	2380	N/A	754	N/A	3330	N/A
Lead	10	13	3	19	12	4
Manganese	260	2300	60	2300	350	101
Nickel	3	140	1	179	4	188
Silver	-	0.4	-	0.6	-	0.6
Zinc	47	36	14	46	50	48

Values in bold type exceed the applicable screening benchmark.

Mn screening value is Tier II (USEPA, 1995); all others are NAWQC (USEPA, 1999). Acute screening value not available for iron. Cr VI NAWQC is used for chromium. See Appendix B for discussion.

Screening values are adjusted for hardness where appropriate.

- Metal concentration was below detection limit. Detection limits were less than or equal to screening values except for silver. See Appendix B for detection limits.

Table 5.7 Total Residual Chlorine Concentrations in Clark Creek (mg/L)

	CLCL02 (above WWTP)	CLCL03 (1 mile below WWTP)	CLCL01 (2.5 miles below WWTP)
Oct. 9, 2001	0.01	0.12	0.05
Jan. 15, 2002	<0.01	0.17	0.02
Jan. 16, 2002	0.01	0.11	0.05
Feb. 5, 2002	<0.01	0.08	0.03

These TRC levels are clearly high enough to be of concern. A chronic toxicity test conducted on the October sampling date passed, but laboratory bioassays are not a reliable indication of the impacts of chlorine on receiving waters. Residual chlorine volatilizes rapidly and much may be lost from the sample during transport to the laboratory and preparation of the sample for toxicity testing, as well as during the test itself. Test organisms are likely to be exposed to much lower levels of chlorine than were present in ambient waters at the time the sample was collected. Whole effluent toxicity tests conducted by wastewater dischargers are generally performed on composite samples, providing an additional opportunity for chlorine to volatilize prior to toxicity analysis.

Tributaries. No bioassays were conducted on tributary streams, but a limited number of analyses were conducted for organic chemicals (see Appendix B). Because of the General Electric facility located on a tributary to Cline Creek, samples from the Cline Creek station (CLCN01) were analyzed for volatile organic compounds on three occasions, all during baseflow. None were detected. In Hildebran Creek (CLHB01), which drains a largely residential area of Newton, no organic compounds (volatile compounds, chlorinated pesticides, organophosphorus pesticides, and nitrogen and acid herbicides) were detected on the one occasion (baseflow) they were sampled. Town Creek was sampled to determine if agricultural activities within the drainage area were contributing current use pesticides and other organic compounds. Metolachlor (a pre-emergent herbicide) was detected in one of two samples, although the observed concentration (0.87 µg/L) was well below levels of concern suggested by the literature (see Appendix B).

5.3.2 Toxicity: Other Data

To support potential development of a copper TMDL by DWQ in April 2001, the Newton WWTP began monthly sampling for copper in Clark Creek above and below the Newton outfall. The upstream station was located on Clark Creek at McKay Road (SR 2014). The downstream location was at SR 2007 approximately 30 meters downstream from CLCL01. Median values for copper through September 2001 were 4.5 ug/L upstream and 5.0 ug/L below the discharge. The highest reading was 9.0 ug/L at the upstream location. Effluent monitoring data reported by the Newton WWTP indicate a median effluent concentration for copper of 10 ug/L for the period from March 2000 to September 2001.

5.3.3 Dissolved Oxygen

Dissolved oxygen (DO) was evaluated using several approaches. DO was measured when samples were collected for laboratory analysis. Additionally, DO was measured on many occasions during watershed reconnaissance and stream survey activities. Finally, data sondes--multiparameter probes with a data logging capability--were deployed simultaneously for four days in August 2001 to assess patterns in DO over several daily cycles at four locations in the watershed (CLCL03, 1.0 mile below Newton's discharge; CLCL02; CLCL06; and CLCL07).

The DO concentrations observed were always well above levels that would negatively impact fish or benthic macroinvertebrate communities. While results from the data sonde deployments did indicate a typical daily DO cycle with minimum levels occurring overnight, the lowest observed DO during these deployments was 6 mg/L. The lowest observed during regular sampling activities was 5.8 mg/L.

5.3.4 Source Area Evaluation

Martin Marietta Quarry. The Martin Marietta Quarry is located north of I-40 in the headwaters of Clark Creek, approximately 7 miles (11.2 km) above Southside Park and the bottom of the upper study area. To assess potential water quality impacts associated with the quarry's discharge, we sampled for selected ions and metals upstream and downstream of the quarry (CLCL08 and CLCL09). Samples were collected at on two occasions during baseflow conditions in the spring of 2001. Selected results are shown in Table 5.8. All parameters were significantly higher downstream of the quarry with the exception of zinc, which was higher at the upstream location. See Appendix B for a complete listing of parameters.

Table 5.8 Median Concentrations of Selected Parameters Above and Below Martin Marietta Quarry

Parameter	CLCL09 Clark Creek at 16 th St.— Above Quarry	CLCL08 Clark Creek at I-40 Exit 126—Below Quarry
Specific Conductance (µS/cm)	100.5	205.0
Total Dissolved Solids (mg/L)	104.5	105.5
Total Suspended Residue (mg/L)	2.20	12.30
Turbidity (NTU)	4.86	15.85
Calcium (mg/L)	8.69	20.65
Sulfate (mg/L)	2.18	30.05
Aluminum (µg/L)	108.5	380.0
Iron (µg/L)	350.5	613.0
Manganese (µg/L)	29.65	158.0
Zinc (µg/L)	15.9	4.85

General Electric Facility. An abandoned General Electric (GE) facility (RCRA permit No. NCD003237948-R1) is located north of I-40 in the Cline Creek drainage. The plant manufactured industrial electrical components from 1956 until it closed in January 1997 due to production problems. The facility currently holds two state water quality permits, one for stormwater and one for groundwater remediation. As part of the groundwater remediation requirement, GE has monitored surface waters at a number of locations since 1983. Monitoring for volatile organic compounds is ongoing in two unnamed tributaries to Cline Creek, one running to the west of the plant and one to the east.

Concentrations of PCE (tetrachloroethene) in the western tributary below the facility were consistently above Tier II chronic screening levels. Four analyses conducted by GE during 2000 and 2001 found PCE levels of 95, 170, 160 and 210 µg/L, compared to the Tier II benchmark of 98 µg/L. Further downstream, near the mouth of the tributary, sampling was discontinued in 1994 because values were consistently below 5 ppb. TCE was detected in the eastern tributary but at levels well below the Tier II value of 47 µg/L.

Section 6

Channel and Riparian Conditions

The characterization of stream habitat and riparian area condition at benthic macroinvertebrate sampling sites, described earlier, provides information essential to the assessment of conditions in the Clark Creek study area. However, a perspective limited to a small number of locations in a watershed may not provide an accurate picture of overall channel conditions, nor result in the identification of pollutant sources and specific problem areas. This study therefore undertook a broader characterization of stream condition by examining large sections of the Clark Creek channel network. This characterization is critical to an evaluation of the contribution of local and regional habitat conditions to stream impairment and to the identification of source areas and activities.

During the course of this study, project staff walked approximately 12 miles (19 km) of channel, including much of the Clark Creek mainstem above SR 2007 (near Maiden) and several miles of tributary channel. Some sections were surveyed on numerous occasions. This section summarizes channel and riparian conditions and discusses likely future changes in stream channels. Results of several geomorphic assessments conducted by North Carolina State University (NCSU) as a part of this study are also summarized. A more detailed description of existing conditions is included in Appendix D, along with additional photographs.

6.1 Summary of Existing Conditions

6.1.1 Overall Channel and Riparian Condition

Channel Conditions. Clark Creek and its tributaries are highly incised. Stream banks are steep and often poorly vegetated. Areas of bank erosion are common (Exhibit 6.1). Channelization impacts are summarized below. Historic channelization aside, streams have been moved or piped in places, most notably at the several crossings of I-40. The use of culverts and riprap is extensive in the upper part of the study area.

In upstream reaches, above the extent of historic channelization, coarser substrate (e.g., cobble and small boulders) is common and local habitat is improved. However, these headwater reaches drain highly impervious areas served by storm sewer systems. They are thus subject to considerable hydraulic stress and possess few if any intact areas upstream from which macroinvertebrate recolonization may occur following disturbance.

Even non-channelized tributaries are often incised (Exhibit 6.2). In many areas this is likely due in large part to downcutting that occurred following the lowering of local base level with the channelization of the mainstem. The more recent effects of urbanization are apparent in the headwaters, in Hildebran and Cline Creeks, and in Town Creek upstream of the Smyre Creek confluence. Other contributing factors may include floodplain accretion during past periods of high agricultural activity and poor management practices.



Exhibit 6.1 Bank erosion in Clark Creek



Exhibit 6.2 Incision and bank erosion in Cline Creek

Riparian Conditions. Although no buffer requirements exist for Clark Creek or its tributaries, trees line the banks of most stretches of these streams. In many places, this tree line is only a few yards wide, giving way to mowed utility right-of-way, pasture, golf course or pavement. Stormwater culverts generally bypass existing riparian buffers. Along the mainstem, in the lower half of the study area and continuing downstream, are extensive former floodplains (present day terraces) just below upland areas but above the present day floodplain areas. Several such areas are intensively managed as irrigated turf farms. As discussed previously, sand dredging activity occurs along this lower reach of the stream, downstream of SR 2012.

Aquatic Habitat. Habitat for aquatic organisms is highly degraded. The bottom substrate at most locations is largely mobile sand, often several feet deep, which provides an unstable habitat for aquatic macroinvertebrates and fish (Exhibit 6.3). With every storm event, much of this sand is mobilized and sandbars shift location. The abrasive, scouring action of the moving sand is also detrimental to organisms which are using submerged tree trunks, roots and other available stable habitats in the stream. Riffles are generally absent except in the headwaters. Most pool habitats are temporary, associated with woody debris that moves frequently during storms. The majority of the channelized stream consists of shallow sandy runs with extensive sand deposits which scour the bottom as they move downstream during high flow events. Bank habitat is often sparse due to bank failure and erosion, or inaccessible due to incision.

NCSU Assessments. As a part of this study, DWQ contracted with the Stream Restoration Institute at NCSU to conduct a morphological evaluation and restoration feasibility study of three reaches:

- Clark Creek at Southside Park in Newton. This reach, located at the downstream end of the upper study area, is typical of much of the Clark Creek mainstem.
- Clark Creek adjacent to the Martin Marietta quarry in Hickory. This area, described in Appendix D, contains a large headcut and is unique in the study area (Exhibit 6.4).
- Cline Creek upstream of Old St. Pauls Church Road. This reach is typical of many tributary channels in the developed upper portion of the study area.



Exhibit 6.3 Uniform depth, lacking riffles and pools



Exhibit 6.4 Waterfall (headcut) at downstream edge of quarry

These evaluations included a visual assessment of stream morphology, pebble counts, longitudinal and cross-sectional surveys, and other field activities. Bank pins and permanent cross-sections were installed so that future changes in channel morphology can be monitored. These evaluations are documented in three reports by NCSU (2001, 2002a, 2002b). Table 6.1 summarizes basic geomorphic parameters for the three reaches. The restoration implications of this work will be addressed in Section 8.

These assessments indicated that the Southside Park and Cline Creek reaches, with conditions typifying much of the channel network, are incised, low width/depth ratio, E type channels (Rosgen, 1996). The NCSU evaluations concluded that these reaches are laterally unstable and likely to widen further in the future (NCSU, 2001 and 2002b). The Cline Creek reach reflects the steeper slopes and generally coarser substrate of headwater tributaries. The NCSU survey of the reach of Clark Creek near the quarry indicated that massive amounts of soil have eroded into the stream at this location (NCSU, 2002a). Ongoing lateral erosion is evident as well as the vertical instability associated with upstream migration of the headcut.

Table 6.1 Selected Geomorphic Characteristics of Three Reaches Evaluated by NCSU

	Clark Creek at Southside Park, Newton	Clark Creek at Quarry, Hickory	Cline Creek above Old St. Pauls Church Rd.
Width/Depth Ratio ¹	6.0	10.7	5.5
Entrenchment Ratio ²	2.4	1.2	>2.2
D ₅₀ (mm) ³	0.9 (sand)	34 (large gravel)	9.4 (medium gravel)
Slope (%)	0.08	3.0	0.32
Sinuosity ⁴	1.0	1.2	1.2
Rosgen Stream Type ⁵	E5	G4	E4
Bank Height Ratio ⁶ (range)	1.2-1.5	1.8-6.7	1.0-1.7

Source: NCSU 2001, 2002a and 2002b

1. Bankfull width/mean bankfull depth
3. Median diameter of channel material
5. Rosgen (1996)

2. Floodprone area width/bankfull channel width
4. Valley slope/channel slope
6. Low bank height/ max bankfull depth

6.1.2 Channelization and Hydrologic Impacts

For most of its length, Clark Creek is a highly modified uniform channel system. The channelization of the early 20th Century, which itself followed extensive agricultural sediment inputs, resulted in a stream which was largely straight and devoid of material coarser than sand. Coarse substrate suitable for riffles had been removed during dredging, while bedrock and large boulders were removed by blasting. The straightening, deepening and widening of the stream resulted in a channel system with little habitat diversity.

The direct impacts of channelization have since been eclipsed by other forces, including channelization's indirect effects, which have persisted for decades. With the modification of sinuosity and slope and creation of high stream banks, channelization often sets in motion an extended period of systemic instability characterized by channel incision and subsequent widening (Schumm et al., 1984; Brookes, 1988; Darby and Simon, 1999). These channel adjustments affect the stability of both the channelized areas themselves as well as unchannelized tributaries, which incise in response to changes in their base level, potentially resulting in the 'rejuvenation' of the entire drainage network (Schumm et al., 1984). These long-term processes generate large amounts of sediment due to bed and bank erosion, resulting in highly unstable stream habitat, and increase the vulnerability of the stream to changes in watershed hydrology (e.g., due to subsequent urbanization). These processes have been at work in Clark Creek for decades and can be observed today.

6.2 Future Changes

Clark Creek is currently evolving in response to multiple disturbances—most notably the lingering systemic response to channelization and the response to more recent changes in watershed hydrology associated with urbanization. Incision has previously occurred throughout the channel system. For most of its length, Clark Creek is in a stage of channel widening. Incised streams that have begun widening generally continue to do so until the channel width is sufficient to allow for the stabilization of slumped banks and a new geomorphic floodplain develops within the incised channel (Schumm et al, 1984; Simon 1989; Simon and Darby, 1999). There is little doubt that this scenario is being played out in Clark Creek.

Particularly in the upper watershed, this recovery process has been complicated by construction related sediment inputs and, more importantly, by the increase in stormwater volumes and peak flows associated with increasing levels of watershed imperviousness. Without intervention, natural processes will continue to widen Clark Creek until a stable morphology is reached, a process that will likely take decades. Give the existing substrate and the lack of grade control, further incision may occur, depending upon the extent and intensity of future development and the nature of associated stormwater management practices. Additional incision would likely result in even further channel widening and delay the process of recovery.

Section 7

Analysis and Conclusions: Causes and Sources of Impairment

This section analyzes the likely causes of impairment in the Clark Creek watershed, drawing upon the information presented earlier in this report. The sources or origin of these key stressors are also discussed.

7.1 Analyzing Causes of Impairment

The following analysis summarizes and evaluates the available information related to candidate causes of impairment in order to determine whether that information provides evidence that each particular stressor plays a substantial role in causing observed biological impacts. A strength of evidence approach is used to assess the evidence for or against each stressor and draw conclusions regarding the most likely causes of impairment. Causes of impairment may be single or multiple. All stressors present may not be significant contributors to impairment. [See the Background Note “Identifying Causes of Impairment”, presented in Section 1, for additional discussion.]

7.1.1 *A Framework for Causal Evaluation—the Strength of Evidence Approach*

A ‘strength of evidence’ or ‘lines of evidence’ approach involves the logical evaluation of all available types (lines) of evidence to assess the strengths and weaknesses of that evidence in order to determine which of the options being assessed has the highest degree of support (USEPA, 1998; USEPA, 2000). The term ‘weight of evidence’ is sometimes used to describe this approach (Burton and Pitt, 2001), though this terminology has gone out of favor among many in the field because it can be interpreted as requiring a mathematical weighting of evidence.

This section considers all lines of evidence developed during the course of the study using a logical process that incorporates existing scientific knowledge and best professional judgment in order to consider the strengths and limitations of each source of information. Lines of evidence considered include benthic macroinvertebrate community data, habitat and riparian area assessment, chemistry and toxicity data, and information on watershed history, current watershed activities and land uses, and pollutant sources. The ecoepidemiological approach described by Fox (1991) and USEPA (2000) provides a useful set of concepts to help structure the review of evidence. The endpoint of this process is a decision regarding the most probable causes of the observed biological impairment and identification of those stressors that appear to be most important. Stressors are categorized as follows:

- **Primary cause of impairment.** A stressor having an impact sufficient to cause biological impairment. If multiple stressors are individually capable of causing impairment, the primary cause is the one that is most critical or limiting. Impairment is likely to continue if the stressor is not addressed. All streams will not have a primary cause of impairment.

- **Secondary cause of impairment.** A stressor that is having an impact sufficient to cause biological impairment but that is not the most critical or limiting cause. Impairment is likely to continue if the stressor is not addressed.
- **Cumulative cause of impairment.** A stressor that is not sufficient to cause impairment acting singly, but that is one of several stressors that cumulatively causes impairment. A primary cause of impairment generally will not exist. Impairment is likely to continue if the various cumulative stressors are not addressed. Impairment may potentially be addressed by mitigating some but not all of the cumulative stressors. Since this cannot be determined in advance, addressing each of the stressors is recommended initially. The actual extent to which each cause should be mitigated must be determined in the course of an adaptive management process.
- **Contributing stressor.** **A stressor that contributes to biological degradation and may exacerbate impairment but is not itself a cause of impairment. Mitigating contributing stressors is not necessary to address impairment, but should result in further improvements in aquatic communities if accomplished in conjunction with addressing causes of impairment.**
- **Potential cause or contributor.** A stressor that has been documented to be present or is likely to be present, but for which existing information is inadequate to characterize its potential contribution to impairment.
- **Unlikely cause or contributor.** A stressor that is likely not present at a level sufficient to make a notable contribution to impairment. Such stressors are likely to impact stream biota in some fashion but are not important enough to be considered causes of or contributors to impairment.

7.1.2 *Candidate Stressors*

As outlined in Section 3, the primary candidate causes of impairment evaluated were:

- Low dissolved oxygen (DO).
- Habitat degradation due to sediment deposition and substrate instability.
- Potential toxicity due to nonpoint source inputs or the Newton WWTP discharge.
- Nutrient impacts from the Newton WWTP or other sources.

7.1.3 *Review of Evidence*

The Clark Creek mainstem is impaired for its entire length within the study area. Tributary streams, including Cline and Town Creeks (within the study area) as well as Pinch Gut and Carpenter Creeks (below the study area), are not considered impaired, but show varying degrees of impacts. Conditions in Cline Creek appear to have improved from past surveys, consistent with removal of a WWTP discharge, while Carpenter Creek showed some decline in biological quality (see Section 4).

Low Dissolved Oxygen (DO). Low dissolved oxygen was considered as a candidate cause of impairment due to the Newton WWTP discharge, other possible sources of organic inputs, and the lack of reaerating riffles in Clark Creek. Two lines of evidence are relevant here: water quality monitoring data and benthic community data. Neither provides any support for low DO

impacts. Benthic community composition is not consistent with pervasive impacts from low DO levels. Monitoring of dissolved oxygen levels in Clark Creek and its tributaries, at a variety of times and locations, upstream and downstream of the WWTP, provided no evidence of low DO concentrations (Section 5), even during low flow warm weather conditions.

Habitat degradation due to sediment deposition and substrate instability. Initial reconnaissance indicated that habitat in the mainstem of Clark Creek and its larger tributaries appeared to be substantially degraded. This factor clearly warranted consideration as a contributor to biological impairment. Relevant lines of evidence include benthic macroinvertebrate community data, habitat and geomorphic evaluation, and watershed history and characteristics.

The watershed has a long history of activities which can impact habitat on a broad scale. These include: 1) substantial inputs of agricultural sediment; 2) several rounds of dredging and direct channelization; 3) channel degradation and widening (including tributaries) in response to channelization; 4) sediment inputs from large scale construction activity; and 5) channel erosion and substrate instability in response to modified watershed hydrology accompanying development.

As described in Sections 4 and 6, bottom substrate in Clark Creek at most locations consists of deep deposits of unstable sand. Riffles and pools are infrequent and habitat is poor. Macroinvertebrate sampling at all mainstem locations showed impairment (Section 4). Habitat at unimpaired tributary sites, though often degraded, was better than at the channelized mainstem locations (e.g., more frequent or larger riffles). Pinch Gut Creek, for example (a reference tributary below the study area), though incised and sandy, had better habitat than the channelized portions of Clark Creek and supported a reasonably diverse benthic community. It appears that most of the habitat degradation occurred some time ago, and that a degree of recovery has occurred.

Reach-scale (local) habitat in the mainstem of Clark Creek above the channelized area is better than downstream. Clark Creek at 16th Street in Hickory has greater habitat and substrate diversity than any other location sampled in Clark Creek, yet supported only a highly degraded benthic community. Regional scale factors are not favorable here, however. This site drains a 1.2-square mile watershed that is highly developed--47% of the drainage consists of industrial and commercial land uses and roads make up an additional 15%. Stream biota are likely subjected to extensive scour during storms. Further, Clark Creek above this site is a small stream with no intact tributaries (most have been culverted or incorporated into the storm sewer system) that can provide a ready source of recolonization following disturbance (see the Background Note "The Stress-Recovery Cycle"). This factor may be an important constraint on the biological potential of this site.

Benthic community composition in the channelized portions of the stream is consistent with habitat impacts. A review of taxa did not find indications of factors such as organic enrichment. Substantial indicators of potential toxic impacts are limited to the unchannelized headwaters of Clark Creek. Historic sampling in the lower reaches of the study area (SR 2012) appears to indicate a decline in biological condition between 1984 and 1990. Whether this is due to habitat deterioration caused by urban development, following partial recovery from channelization, or

Background Note: The Stress-Recovery Cycle

Even in relatively pristine streams, aquatic organisms are exposed to periods of stress. Natural stresses due to high flows during storms, low flows during hot dry summer periods or episodic large sediment inputs (e.g., from slope failures in mountain areas or breaching of beaver dams) can have significant impacts on stream communities. Although aquatic communities in high quality streams may be impacted by such disturbances, and some species may be temporarily lost from particular sites, populations are able to reestablish themselves--often very quickly--by recolonization from less impacted areas or refugia (see Yount and Niemi, 1990; Niemi et al., 1990). This process can involve recolonization from backwater areas, interstitial zones (spaces between the cobble and gravel substrate), the hyporheic zone (underground habitats just below the streambed surface layer) or other available microhabitats. Repopulation from headwaters or tributary streams not impacted by the disturbance can also occur. For insects, aerial recolonization is important as well.

Without robust mechanisms of recovery, even streams subjected to relatively modest levels of disturbance would be unable to support the diversity of aquatic organisms that they often do (Sedell et al., 1990; Frissell, 1997). This balance between local elimination followed by repopulation is critical to the persistence of fish, macroinvertebrates and other organisms in aquatic ecosystems, and is part of what we mean when we say that these creatures are “adapted” to their environment.

It is now commonly recognized that as watersheds experience increased human activity, stream biota are subjected to higher levels of stress. This can include both an increased frequency, duration or intensity of ‘natural’ types of disturbance, such as high flows, as well as completely new stresses, such as exposure to chlorinated organic chemicals. We less often realize, however, that many of these same activities often serve to inhibit those mechanisms that allow streams to recover from disturbances--in particular movement and recolonization (Frissell, 1997). For example, as watersheds develop:

- channel margin and backwater refugia may be eliminated as bank erosion or direct channel modification (channelization) make channel conditions more uniform and habitat less diverse;
- edge habitat, such as root mats, may be unavailable to biota due to lowered baseflows;
- access to interstitial and hyporheic areas may be limited by sediment deposition;
- impoundments may limit or eliminate drift of organisms from upstream;
- small headwater and tributary streams may be eliminated (culverted or replaced with storm drain systems);
- remaining headwater and tributary streams may be highly degraded (e.g., via channelization, removal of riparian vegetation, incision and widening due to increased stormflows, or decreased baseflows);
- aerial recolonization of macroinvertebrates may be diminished by the concomitant or subsequent degradation of streams in adjacent watersheds; and
- fish migration is often limited by culverts or other barriers.

As human activity intensifies, aquatic organisms are thus subjected to more frequent and more intense periods of stress, while at the same time their ability to recover from these stresses is severely compromised. It is the interaction between these two processes that results in the failure of many streams to support an acceptable population of fish or macroinvertebrates.

Efforts to restore better functioning aquatic communities in degraded streams must consider strategies to both reduce the stresses affecting stream biota and to protect and restore potential refugia and other sources of colonizing organisms. Under some conditions, the lack of adequate recolonization sources may delay or impede recovery. Protecting existing refugia and those relatively healthy areas that remain in impacted watersheds should be an important component of watershed restoration efforts (McGurrian and Forsgren, 1997; Frissell, 1997).

due to other stresses, cannot be determined. Habitat evaluation data are not available for the 1984 and 1990 sampling events.

Potential toxicity due to nonpoint source inputs and/or the Newton WWTP discharge. Toxicity was evaluated as a potential contributor to impairment due to the diverse range of land uses and

source activities in the watershed and the presence of a major wastewater discharge. Four lines of evidence are relevant: benthic community data; water quality monitoring data collected during the course of the study; in-stream bioassay data; and effluent monitoring data.

The benthic community downstream of the WWTP was rated as Fair (impaired), similar to those locations upstream of the WWTP discharge (Section 4) for which ratings could be assigned. While the community included many pollution-tolerant taxa, community composition was not strongly indicative of specific toxic impacts.

Several metals exceeded NAWQC on occasion (Section 5), but only total metals concentrations were analyzed and bioavailability could not be evaluated. On-site total residual chlorine measurements indicated high concentrations (generally at least ten times chronic NAWQC values) one mile below the WWTP outfall (see Section 5).

The toxicity tests performed for this study, and the whole effluent bioassay tests conducted by the Newton WWTP during this period, even though each resulted in a “pass”, cannot be used to rule out the possibility of in-stream chlorine toxicity. Chlorine is extremely volatile and toxicity test conditions are not representative of in-stream chlorine levels (see Section 5). A recognized limitation of static renewal whole effluent toxicity test procedures, such as those employed in the DWQ NPDES program, is the evaluation of toxicity due to volatile or transient toxicants.

While benthic community composition (the types and abundance of benthic organisms present) can be a useful indicator of the nature of the stressors impacting a stream, impacts from one type of stressor can make it difficult to identify impacts due to other causes. Though toxic impacts could not be verified by benthic data due to a lack of the specific taxa needed to do a toxic screening, the in-stream chlorine levels observed were clearly high enough to pose a substantial risk of toxicity, and must be viewed as having a significant potential to contribute to impairment for some portion of the stream below the outfall.

In the upper study area, benthic community composition provides some indication of toxicity at the headwater site (Clark Creek at 16th St.) but not further downstream. This community includes a number of highly tolerant taxa that can be indicative of toxic impacts. Toxicity bioassays and chemical sampling were not performed at this location. Six bioassays (4 baseflow, 2 stormflow) performed several miles downstream (at Southside Park in Newton) provided little indication of toxic conditions. As was the case in the lower watershed, several metals exceeded NAWQC on occasion (Section 5), but only total metals concentrations were analyzed and bioavailability could not be evaluated. Associated bioassays all passed.

Reach scale habitat at the 16th Street sampling location on Clark Creek was good, though regional habitat issues are a concern. This site is probably subject to significant hydraulic stress due to the considerable upstream imperviousness, and possesses few if any upstream areas to serve as recolonization sources (Section 6 and Appendix D). Both toxicity and these broader habitat concerns probably contribute to impairment at this location.

Metolachlor, a commonly used herbicide, was detected in storm samples at several sites. Observed concentrations were well below thresholds suggested by the literature (Appendix B) and acute bioassays conducted on samples collected at the same time passed. Available data are

not adequate to fully characterize pesticide concentrations in Clark Creek, but existing information does not provide a strong indication that a problem exists at present.

Concentrations of PCE (tetrachloroethene), a volatile organic compound, are consistently above the Tier II chronic screening value in a tributary to Cline Creek, downstream of a former General Electric manufacturing plant (Section 5). PCE has not been detected in Cline Creek itself, however, and benthic macroinvertebrates in Cline Creek are relatively diverse compared to other streams in the study area. It appears that if toxic conditions exist due to elevated PCE, they are likely limited to a portion of the tributary.

Toxic impacts, especially if caused by stormwater inputs, can be very episodic and difficult to identify. Even though toxicity analyses were performed on seven occasions and evidence of toxicity was not found, one cannot rule out toxicity at other times due to the occurrence of spills or infrequent incidents that occurred in between sampling events. The fact that the benthic community composition does not strongly indicate toxic impacts except for the most upstream location provides important corroboration that toxic impacts are probably not a major contributor to impairment in most of the portions of Clark Creek studied during this investigation.

Nutrients. Our initial review of macroinvertebrate data indicated that nutrients were not a likely cause of impairment, but further evaluation was conducted due to the presence of the wastewater discharge. Nitrogen and phosphorus concentrations in Clark Creek (Section 5) are clearly elevated. The biological response of free flowing streams to nutrients is highly variable, however, and depends upon shading, stream velocity and other factors. It is thus difficult to use in-stream nutrient concentrations to determine whether nutrients are a cause of benthic impairment. Further interpretation of macroinvertebrate data, for sites both above and below the discharge, indicates that benthic community composition in Clark Creek is not consistent with significant impacts due to organic enrichment or nutrient inputs (Section 4). Prolific levels of algal growth were not observed in the stream. It does not appear that nutrients are contributing to impairment in Clark Creek.

7.1.4 Conclusion

Multiple lines of evidence support the conclusion that habitat degradation is a primary cause of impairment in most of the Clark Creek study area. Toxicity from nonpoint source inputs, together with scour and a lack of recolonization sources, are cumulative causes of impairment in the Clark Creek headwaters. While it is possible that these toxic impacts extend further downstream, there is currently no significant evidence that this is the case. Toxicity due to chlorine discharged from the Newton WWTP is a likely secondary cause of impairment for at least a mile below the outfall.

7.2 Sources of Impairment

The reasons for habitat degradation are multiple, including hydromodification of several types and, to a lesser degree, sediment inputs from upland areas. EPA defines hydromodification (source category 7000) as the alteration of the hydrologic characteristics of surface waters resulting in degradation of resource conditions (USEPA, 1997). Two types of hydromodification

are the primary reasons for habitat degradation in the study watershed: channelization (alteration of channel morphology, dredging); and higher stormflows due to the increase in impervious surfaces associated with development.

The historic channelization of the stream, discussed earlier, had both direct negative impacts on channel conditions and aquatic habitat and enduring indirect effects on bank stability. Considerable bank erosion occurred over a period of decades as Clark Creek incised and then widened. With the incision of Clark Creek, tributary streams that had not been channelized incised due to a lowering of local base level, degrading habitat in those streams and providing an additional source of sediment to Clark Creek. These processes of channelization and incision, which result in high, steep banks with inadequate vegetative protection, also made Clark Creek and its tributaries more vulnerable to future disturbances. Trees continue to be undercut and topple into the stream, and the associated soil becomes stream sediment.

Impervious areas associated with rooftops, roads and parking areas have greatly altered the hydrologic characteristics of the study area, especially in the upstream portion. Much rainfall that previously infiltrated into the soil or gradually flowed into streams through feeder channels now falls on impervious areas and is collected by storm sewers which efficiently route runoff to major streams. The resulting increase in the stormflows (peak flows as well as the total volume of stormwater) can often be sufficient in itself to cause bank erosion and/or incision. Indeed this is occurring in the headwaters of Clark Creek. Where banks were already in poor condition due to past activities, as is the case in much of the watershed, severe bank erosion is all but certain.

The headcut on Clark Creek in the area of the Martin Marietta quarry, above the area of historic channelization, is also a continuing source of sediment (see Section 6). The gully below the headcut provides mass wasting inputs to the channel, which are then gradually carried off by the stream. If the headcut is allowed to gradually work its way upstream, it will deepen the channel and cause additional bank instability.

While most sediment observed in the stream likely has its origins within the channel system, inputs of sediment from eroding upland areas are also a factor. As discussed in Sections 2 and 6, agriculture was an important source of sediment historically, but has not been significant recently in the study area and is not likely an important contributor to impairment. Given the level of construction activity in the I-40 corridor area over the past 20 years, it is likely that substantial sediment inputs from those activities occurred. Whether substantial quantities of this material remains in the channel network is not clear. Current upland sources of sediment include road building and other construction activities concentrated in the Tate Blvd./I-40 corridor in Hickory and Conover.

The particular toxicants responsible for toxic impacts in the headwaters of Clark Creek have not been identified. There are many potential sources in the headwaters area, which is dominated by major highway arteries, commercial areas and a wide variety of industrial activities. Inputs could enter the stream with storm runoff, though periodic spills or unpermitted connections to the storm sewer system are also possibilities.

7.3 Other Issues of Concern

Though data on fish communities in Clark Creek is lacking, habitat for fish is very poor, due in large part to sedimentation. Riffle areas, important for many stream species, are absent from most reaches. Pools are transitory and primarily small. Bank cover is uncommon.

The sediment transported by Clark Creek continues to have negative resource impacts after it leaves the study area. This material, whether its origin lies within the channel or in eroding uplands, eventually ends up in the South Fork Catawba River and then Lake Wylie, where it continues to degrade habitat and reduce reservoir capacity.

Though the existing evidence does not support a conclusion that nutrients are a cause of biological impairment in the Clark Creek study area, nitrogen and phosphorus levels are clearly high, especially downstream of the Newton WWTP. Clark Creek is an important source of nutrients to the South Fork Catawba River and Lake Wylie.

Section 8

Improving Stream Integrity in Clark Creek: Recommended Strategies

As discussed in the previous section, the most important causes of impairment in Clark Creek are: habitat degradation in most of the watershed caused by hydromodification; chlorine toxicity in the area below the Newton WWTP; and, in the headwaters area, the cumulative effects of scour and toxicity due to unidentified sources. Future development may also pose a threat to streams in the Clark Creek watershed due to the potential for additional sediment inputs during construction and modification of watershed hydrology that will yield increased stormflows. This section discusses how these problems can be addressed. A summary of recommendations is included at the end of the section.

8.1 Addressing Current Causes of Impairment

The objective of efforts to improve stream integrity is to restore water quality and habitat conditions to support a diverse and functional biological community in Clark Creek. Over the past century Clark Creek has experienced major physical disturbance. Because channel instability and degraded aquatic habitat are so widespread, bringing about substantial improvement in physical conditions will be a tremendous challenge. Yet the watershed has not been so highly modified as to preclude significant improvements in stream integrity. Watershed imperviousness in the more developed upper portion of the study area ranges from approximately 20% to 30%—high enough to cause hydrologic impacts but not to preclude restoration opportunities. Vegetated riparian areas remain along a significant portion of major stream corridors. A return to the relatively unimpacted conditions that probably existed prior to widespread agriculture is unlikely, but Clark Creek can potentially support a healthier community than it does today. The exact extent of biological improvement that will occur as habitat and water quality are restored is difficult to predict.

8.1.1 *Habitat Degradation--Sedimentation and Substrate Instability*

This section outlines a general approach to improving habitat conditions in Clark Creek and discusses more specific recommendations for initiating restoration efforts.

a. Background

Habitat deterioration in Clark Creek is driven by hydromodification of two types—long-term adjustments to past channelization, and the hydrologic impacts of recent and ongoing development. The impacts of these disturbances have been cumulative and are difficult to differentiate. In the absence of further management actions, substantial channel adjustment, with resulting poor habitat for fish and macroinvertebrates, will likely continue until development in the watershed slows and the stream has had an adequate time to develop a channel morphology in equilibrium with the stabilized hydrologic conditions of the watershed. Given the significant hydrologic alteration of several subwatersheds (Clark Creek headwaters, Miller Branch, Cline

Creek and Hildebran Creek), greatly improved aquatic habitat may not follow stream stability, even after a substantial period of time. The hydrologic regime in the urban environment can produce frequent periods of high velocity scouring flows. Low baseflows and a wide baseflow channel may also limit biological potential. Sedimentation would likely be less significant once the channel stabilizes. However, the altered hydrologic conditions associated with increased development, if not at least partially mitigated, are likely to result in conditions which would make it extremely difficult to sustain substantial improvements in aquatic communities.

b. Improving Aquatic Habitat—A General Approach

Both stream channel restoration and stormwater retrofits to control stormwater volume and peak flows are necessary to address the poor habitat conditions in Clark Creek. Specifically:

1. The entire mainstem of Clark Creek below I-40 (approximately 10 miles within the study area, and a similar distance downstream), as well as many tributary channels, must eventually be restored to a stable morphology.
2. Stormwater BMPs to reduce runoff volume and partially restore watershed hydrology must be implemented in the existing developed areas of the Clark Creek headwaters, Miller Branch, Cline Creek, Hildebran Creek and Town Creek drainages. These areas include portions of Hickory, Conover and Newton.
3. Channel restoration and stormwater BMPs must be implemented in an integrated fashion so that both channel morphology and watershed hydrology problems are addressed using a coordinated approach in each subwatershed. Given the scope of the problem, restoration efforts must be implemented incrementally over an extended period of time. Ongoing planning will be a necessity.

Stream channel restoration. Significant improvements in aquatic habitat are unlikely as long as the channel network remains grossly unstable. Over a period of decades, the channel will develop a stable form on its own. The alternative to waiting for this to occur is a large scale stream channel restoration effort to create a stable channel morphology. It is not likely that smaller scale habitat improvement efforts would be adequate to reverse the widespread decline in aquatic habitat. Even if effective in improving habitat in localized areas, such areas would be largely isolated from one another and would not function well ecologically. Further, such an approach would do nothing to address the large sediment loads Clark Creek contributes to the South Fork Catawba River and Lake Wylie, or the loss of streamside property caused by bank erosion.

Since overall channel morphology is unstable, simple bank stabilization will not be effective in addressing existing problems. Stream channel restoration is necessary to reestablish a stable channel dimension (cross sectional dimension), pattern (sinuosity and planform) and longitudinal profile (slope). While other options exist (see NCSU, 2001 and 2002b), the most feasible approach to the restoration of most channels in this watershed is probably to construct appropriate floodplain area and channel form within the existing incised channel (Rosgen Priority 2 or Priority 3 approach). The specific restoration strategy selected will depend upon the stream corridor width available (belt width), among other factors (NCSU, 2001; Rosgen, 1997).

Stormwater retrofits. Relying on channel stabilization and restoration alone to substantially improve aquatic habitat and biological conditions in this watershed does not have a high probability of success. Although channels can be designed to remain stable under existing hydrologic conditions, stress on aquatic organisms (e.g., due to scour during storms) will still be considerable and may often limit the resulting biotic diversity. Partial restoration of watershed hydrology--the mitigation of some of the hydrologic impacts of existing development--is often a prerequisite for the improvement of urban stream habitat.

Stormwater retrofits are structural stormwater measures (best management practices or BMPs) for urban watersheds intended to lessen accelerated channel erosion, promote conditions for improved aquatic habitat and reduce pollutant loads (Claytor, 1999). A range of practices, including a variety of ponds and infiltration approaches, may be appropriate depending on specific local needs and conditions. These issues will be discussed later. Many practices installed to reduce hydrologic impacts will also remove pollutants, though this is highly variable by pollutant and by BMP.

Timing and scope. Improving habitat conditions in the mainstem of Clark Creek is a long-term objective, but restoration of Clark Creek below I-40 should not be undertaken in the short run. The mainstem will be difficult, if not impossible, to restore as long as sediment loads (from upstream bank erosion and upland construction activities) and uncontrolled stormwater flows from tributary and headwaters areas continue unabated. Short-term goals must therefore focus on the restoration of these smaller subwatersheds. Restoration of the mainstem of Clark Creek should be approached after upstream sediment sources have been controlled and upstream hydrologic conditions have been mitigated to the extent feasible.

Given the size of the watershed, restoration will be a task of substantial proportions. Specific projects must be designed and implemented incrementally over an extended period of time. Improvement in stream condition is also likely to be incremental. Individual subwatersheds should be the operational unit for planning and implementation (Caraco et al., 1998). Subwatersheds in the Clark Creek study area, which generally range from two to seven square miles in area, are an appropriate size for productive watershed planning. Considering the scope of activities, logistical complexities and scientific uncertainties, it is not possible to anticipate all necessary actions in advance. Restoring Clark Creek and urban streams, generally, requires an iterative process in which sequential efforts are implemented over time in conjunction with an effort to monitor changes in stream condition and plan subsequent actions.

While it is not possible to outline all steps in advance, we can chart an initial direction for restoration. The following section proposes a set of restoration activities for the Cline Creek subwatershed as the first priority area to be addressed. Organizational and planning issues are discussed further in Section 8.3.

Watershed restoration of the type necessary to significantly improve Clark Creek is clearly ambitious, but has become more common over the past decade. Local governments and watershed-based organizations have increasingly sought to plan and implement long-term restoration and management strategies that integrate channel, riparian and watershed measures to address stream issues in an integrated fashion. The most long-standing example is probably the restoration of the Anacostia River in the Washington, DC area, for which planning was initiated

in the 1980s (Anacostia Restoration Team, 1991; Metropolitan Washington COG, 1998; Galli, 1999; Schueler and Holland, 2000). Among the other local areas that have begun to address these issues are Austin, Texas (City of Austin, 2001); Atlanta, Georgia (CH2M HILL, 1998); Montgomery County, Maryland (Montgomery County DEP, 2001); Baltimore, Maryland (Baltimore County DEP, 1997); Charlotte, North Carolina (Stahl, 2001); and Michigan's Rouge River watershed (Cave and Bryson, 2001; Rouge River Project, 2002).

c. Developing a Subwatershed Strategy for Cline Creek

For the reasons discussed below, the Cline Creek drainage is proposed as the initial focus for restoration activities. Cline Creek can serve as an early basis for both technical work and the formation of an organizational framework for watershed restoration and intergovernmental cooperation. The initial practices implemented would serve as pilot projects to help familiarize stakeholders with both the processes and practices of stream channel restoration and stormwater retrofitting. With appropriate monitoring, these efforts would also provide important information regarding the extent and pace of biological improvement that can be expected. Other subwatersheds could be considered as alternative locations for early projects if local stakeholders find those areas more conducive to initiating restoration activities. Each subwatershed must be addressed eventually.

Cline Creek has its headwaters in the western portion of Conover, north of interstate 40 and enters Clark Creek a short distance above Settlemyre Bridge Road (Figure 8.1). The length of the Cline Creek mainstem exceeds three miles, with tributary channels (based on 1:24000 scale topographic maps) several times that length. Impervious areas covered an estimated 21% of the 5.1-square mile watershed in 1998, typical of the upper portion of the study area.

Cline Creek represents a good choice for the initial subwatershed for the following reasons:

- Though degraded, it is in the best biological condition of any stream sampled in the study area, with the highest EPT diversity and lowest BI. Cline Creek, especially if improved, can serve as an important source of macroinvertebrate colonization for the Clark Creek mainstem and is an important building block in the larger restoration effort.
- Much of the watershed is in industrial and commercial uses that often have extensive pervious areas that may have potential for stormwater retrofit locations.
- Because of the largely commercial/industrial land use, streamside lots are much larger than in residential areas. Stream channel restoration would require the cooperation of fewer property owners than in many other locations.
- Much of the stream is bordered by a vegetated riparian area and does not appear to have been channelized, retaining some of its natural sinuosity.
- While primarily in Conover and Newton, the watershed also includes portions of Hickory and unincorporated areas of Catawba County. The multi-jurisdictional nature of the watershed could be viewed as a complicating factor. However, it also provides an opportunity to develop--early in the restoration process--the framework for interjurisdictional cooperation that will be necessary for the success of the larger effort.

Restoration efforts within this subwatershed should include the following measures:

1. Appropriate stormwater retrofit opportunities should be implemented to reduce stormwater volumes and peak flows. Much of the impervious areas to be treated lie north of US 70/321 where most commercial/industrial activity is located. The stream splits into three branches above US 70/321 (the mainstem and two major tributaries). Appropriate retrofit opportunities should be carried out in each of these three catchments.
2. The mainstem of Cline Creek should be restored at least from US 321 to its mouth, a distance of approximately 1.5 miles. Restoration opportunities on major tributaries should also be evaluated. The evaluation conducted by NCSU as a part of this study (NCSU, 2002b) documents current morphology in one reach of Cline Creek and discusses restoration options.
3. Stormwater BMPs should be in place prior to restoration of the Cline Creek mainstem.
4. Forested buffers should be restored in areas in which they do not exist. Property owners should be encouraged to replant native riparian vegetation along tributary channels from which such vegetation has been removed.

Available structural and nonstructural retrofit practices to reduce hydrologic impacts and remove pollutants have been discussed widely in the literature (e.g., ASCE, 2001; Horner et al., 1994) and detailed in state BMP manuals (e.g., NCDWQ, 1999c; Maryland Department of the Environment, 2000). Some of these include:

- detention ponds;
- retention (wet) ponds;
- stormwater wetlands;
- bioretention;
- infiltration structures (porous pavement, infiltration trenches and basins);
- vegetative practices to promote infiltration (swales, filter strips);
- 'run on' approaches (regrading) to promote infiltration;
- reducing hydrologic connectivity (e.g., redirecting of downspouts);
- education to promote hydrologic awareness; and
- changes in design/construction standards.

Determining which BMPs (or which combination of practices) will be most feasible and effective for a particular catchment depends on numerous site-specific and jurisdictional specific issues, including: drainage patterns; size of potential BMP locations; treatment volume needed considering catchment size and imperviousness; soils; location of existing infrastructure; other goals (e.g., flood control, water quality). Considerations in the identification of retrofit sites are discussed by Schueler et al. (1991) and Claytor (1999). A key design challenge is to maximize hydrologic mitigation and/or pollution removal potential while limiting impacts to infrastructure and existing structures.

Recommendations for specific stormwater retrofit projects are beyond the scope of this investigation. Specific projects should be identified as part of the development of a restoration plan for the Cline Creek subwatershed. This plan should be developed with the input of a broad based stakeholder group and should consider water quality goals, other water resource concerns (e.g., flooding) and local infrastructure issues.

DWQ encourages the consideration of a wide range of practices and approaches. Ponds of various types are probably the practice most familiar to many engineers and can indeed be

versatile and cost-effective. Detention alone does not reduce stormwater volume; however though, the rate and timing of discharge are controlled. It is important to carefully examine infiltration practices, including both structures and ‘behavioral’ changes such as redirecting downspouts to pervious areas. While there are clearly limits to the usefulness of infiltration, based on soils, water table levels and other factors (Livingston, 2000), these practices are often underused. Design approaches to minimize runoff volume are also important tools (Caraco et al., 1998; Prince George’s County DEP, 2000). Some retrofit methods may have negative side effects that must be carefully considered. For example, regional wet detention facilities may disrupt recolonization, alter the food/energy source available to downstream biota, and depending upon design and operation, reduce downstream baseflows (Maxted and Shaver, 1999; Schueler, 2000a).

d. Other Issues/Recommendations

The gully and head cut on the mainstem of Clark Creek at the downstream end of Martin Marietta quarry area must be stabilized. In the absence of rehabilitation, the headcut will continue its gradual migration upstream, elongating the gully area and serving as a continuing source of sediment for decades to come. A highly engineered solution is required to stabilize the headcut and allow the stream to dissipate the energy of the large drop in grade (NCSU, 2002a). Given the unique characteristics of the site, a specific engineering study will be necessary to determine the best approach. Cost cannot be estimated with available information.

e. Costs and Constraints

The restoration of channel stability and aquatic habitat in Clark Creek will be a major undertaking in terms of technical planning, project implementation, finances and organizational coordination. Costs will be considerable. Rough cost estimates for channel restoration and stormwater retrofitting for the Cline Creek subwatershed are provided below.

Based on the recent experience of the North Carolina Wetlands Restoration Program (Haupt et al., 2002) and a number of Maryland counties that have active restoration programs (Weinkam et al., 2001), costs of at least \$200 per linear foot should be expected for the restoration of urban stream channels. The restoration of two miles of mainstem channel and two miles of tributary channel (21,120 feet) in the Cline Creek drainage would likely cost on the order of \$4.2 million or more.

Stormwater retrofit costs are difficult to estimate until specific practices and locations have been selected. Unit costs vary greatly with the size of the area treated. Using data from the mid 1990s, Schueler (2000b) reported that typical costs for stormwater ponds were about \$10,000 per impervious acre treated for projects treating 10 impervious acres, but \$5,000 per impervious acre treated for projects covering 100 impervious acres. Cline Creek has approximately 685 impervious acres (5.1 square miles, or 3264 acres, times an imperviousness of 21%). Retrofitting of all impervious areas will be neither necessary nor feasible. Claytor (1999) suggests that a minimum of 50% of a watershed be retrofitted. Assuming a cost of \$7,500 per impervious acre (typical treated area size between 10 and 100 acres), it would cost approximately \$2.6 million to retrofit 350 impervious acres. These estimates are based on data that are several years old and are subject to many uncertainties, but \$6 to \$10 million (over \$1

million per square mile of watershed) can be used as a gross approximation of the costs of a large scale watershed restoration effort in the Cline Creek drainage.

Costs could be reduced to some extent if restoration is planned and implemented in conjunction with capital improvements and infrastructure enhancements (e.g., bridge or sewer line replacement) anticipated by local governments. The potential connection between watershed restoration and infrastructure issues has been increasingly recognized by local governments (e.g., City of Austin, 2001; Montgomery County DEP, 2001). Cost-effective restoration opportunities are also likely as portions of the watershed are redeveloped incrementally over a period of decades (Ferguson et al., 1999).

Restoring the miles of unstable stream channel in the Clark Creek watershed will necessitate working cooperatively with hundreds of property owners. Stream work would be implemented gradually over many years, constituting a major logistical challenge that will require patience, resources and an oversight team dedicated to this activity. For example, restoration of the approximately 1.5 miles of Cline Creek from US 321 to its mouth will involve 15-20 properties. The presence of a sewer line right-of-way along much of the Clark mainstem and several tributaries, including Cline Creek, will be an advantage in terms of access but a constraint in terms of restoration options.

8.1.2 Chlorine Toxicity from the Newton WWTP

It is the responsibility of the Division of Water Quality to insure that chlorine levels in the Newton WWTP effluent are reduced to nontoxic levels as soon as possible. A chlorine limit is appropriate for this facility. The current permit for the Newton WWTP expires in 2005. DWQ will evaluate whether the permit should be modified before that date and will work with the City of Newton to reduce chlorine levels in the discharge. Installation of dechlorination equipment or the use of UV (ultraviolet light) disinfection may be necessary.

8.1.3 Toxicity in the Headwaters Area

Biological data indicate that toxic impacts are likely in the headwaters of Clark Creek above I-40. While impacts extending further downstream cannot be ruled out, there is currently little evidence that this is the case. The toxicants involved and their specific sources remain unknown, although the presence of toxic indicators at the uppermost benthic sampling location (Clark Creek at 16th Street) points to a relatively small (1.2 square miles) catchment. The problem will be difficult to address directly with the existing level of information. Implementing BMPs to address toxicants of unknown origin or characteristics could be extremely inefficient and potentially ineffective.

Stormwater management activities likely to be required of the City of Hickory under its Phase II stormwater permit, most notably the identification and elimination of illicit discharges, may eliminate the problem or at least result in its identification (if source is other than an illicit discharge). Stormwater retrofit measures in the headwaters area, carried out as part of the overall Clark Creek restoration strategy, will also result in some pollutant removal and may result in the attenuation of toxicity. Additional data should be obtained to more narrowly define

the nature and source of the toxicants involved. Periodic biological monitoring should be carried out in the headwaters to determine if the benthic community improves as the result of Phase II activities or stormwater retrofitting.

8.2 Addressing Future Threats

Several portions of the watershed are relatively undeveloped at the present time: 1) the west side of the upper study area below Hickory and west of Newton; 2) much of the lower study area except the portion of Town Creek upstream of its confluence with Smyre Creek. Considerable development is likely in these areas over the next several decades. Without an effort to mitigate the hydrologic impacts of this development or improve sediment and erosion control practices for construction, continued stream degradation in Clark Creek is likely. Addressing these future threats is essential, or improvements resulting from efforts to control current sources of impairment may be short lived or may never materialize. The Phase II stormwater regulations, currently under development, may help assure that future development occurs in a less environmentally damaging fashion than recent growth. Whether these regulations will be sufficient to protect Clark Creek from further degradation cannot be determined at this point.

Aside from the necessity to prevent future tributary degradation from contributing to the continued impairment in Clark Creek, protection is important for several other reasons. First, a decline in the biological condition of tributary streams may result in the classification of additional streams as impaired. Secondly, those tributary streams that currently support a more diverse benthic community than the mainstem are critical to the recovery of Clark Creek. Streams such as Cline Creek, Town Creek and probably some of the smaller tributaries entering Clark Creek from the west serve as sources of recolonization for the mainstem. The preservation and enhancement of these healthier streams is essential to the recovery of the larger system.

8.2.1 *Sediment from New Construction*

Significant future sediment inputs would prolong habitat instability even if existing sources of sediment are addressed. While bank instability is the primary source of sediment in Clark Creek, inputs from construction activities can also be substantial, particularly in the case of large subdivisions or large commercial/industrial projects. Observations during the investigation indicated that substantial erosion often takes place during construction and that significant sediment inputs to streams sometimes occur. Additional sediment inputs from new development can be expected if future sediment and erosion control practices mirror those of the past.

More effective enforcement of sediment and erosion control regulations on the part of the Division of Land Resources and the City of Newton's sedimentation and erosion control program will be essential to the prevention of additional sediment inputs from construction activities. While a complete evaluation of current sediment and erosion control practices is beyond the scope of this study, development of improved erosion and sediment control practices may be beneficial. The CWMTF could consider working cooperatively with regulatory agencies and willing developers to install and monitor innovative approaches that could supplement or serve as alternatives to current practices and requirements.

8.2.2 *Hydromodification Due to Increased Stormflows*

As new development occurs in the Clark Creek watershed, it is likely that stormflows will increase with the expansion of associated impervious areas. Both peak discharges as well as the frequency and duration of high velocity flows can be expected to increase and to negatively affect channel stability. Existing conditions in a watershed can greatly affect a stream's vulnerability to these hydrologic changes (Bledsoe and Watson, 2001). As discussed previously, stream banks throughout the watershed are in poor condition and prone to erosion. Streams in the study area are likely to be highly sensitive to any increase in stormflow. Given these conditions, increased bank erosion and/or incision is likely if significant hydrologic change occurs in the watershed.

New development in the study area is not currently subject to any stormwater requirements, although this will change in the next few years as Hickory, Newton, Conover and Catawba County will be required to comply with the new Phase II stormwater program (see Section 2). This will require, among other measures, as yet unspecified stormwater controls for new development. Whether adherence to these requirements will be sufficient to prevent further degradation of the vulnerable channels in the Clark Creek watershed cannot be predicted. The efficacy of these regulations will depend on the nature of the requirements, how effectively they are enforced, and whether the entire watershed is included.

Whether accomplished through Phase II requirements or voluntary local action, it is important that comprehensive stormwater management practices be implemented. The sensitive channels in this watershed are most likely to be protected from the hydrologic impacts of new development if post construction stormwater requirements include:

1. No net increase in peak flows leaving the site from predevelopment conditions for at least the 1-year 24-hour storm.
2. Active promotion of infiltration practices, innovative development design and other approaches to limit stormwater volume.
3. Application of these requirements to all new development.

8.2.3 *Riparian Buffers*

The protection of riparian buffers is critical to limiting the hydrologic impacts of development and to the attenuation of pollutant inputs. Whether accomplished through incentives or regulatory means, it is important that measures be implemented to protect existing riparian buffers along perennial and intermittent streams.

8.2.4 *Pesticides and Nutrients*

Pesticides are not currently a cause of impairment, but may increase as more of the watershed is developed. Nitrogen and phosphorus inputs do not currently cause major problems in Clark Creek, but do contribute to the nutrient loading to the South Fork Catawba River. Educational efforts directed at homeowners and managers of commercial and industrial areas in the

watershed would be useful to reduce usage of pesticides and fertilizers and/or improve application methods.

8.3 A Framework for Improving and Protecting Stream Integrity

Restoration projects of this scale require an iterative process of ‘adaptive management’ (Reckhow, 1997; USEPA, 2001). An initial round of management actions should be planned and implemented, the results of those activities monitored over time, and the resulting information used as the basis for planning subsequent efforts. Additional measures should be implemented as appropriate. An organizational framework for ongoing watershed management is essential in order to provide oversight over project implementation, to evaluate how current restoration and protection strategies are working, and to plan for the future.

While state agencies can play an important role in this undertaking, planning is often more effectively initiated and managed at the local level. A coordinated planning effort involving local governments in the watershed (Catawba County, Hickory, Conover, Newton and Maiden), as well as a broad range of other stakeholders, will be critical if conditions in Clark Creek are to be improved. This effort must include the development of a long-term vision for protecting and restoring the watershed, as well as the specific work that will be necessary to support a patient approach to planning and implementing projects to move toward that vision.

8.4 Summary of Watershed Strategies for Clark Creek

The most important factors leading to impairment in the study area are systemic in nature. Addressing these problems will require actions that are similarly broad in scope. Mitigating the potential impacts of future watershed development on watershed hydrology is also critical, or improvements resulting from efforts to control current sources of impairment may be short lived.

The following actions are necessary to address current sources of impairment in Clark Creek and prevent future degradation. Actions one through six are all essential to the restoration of aquatic communities throughout the Clark Creek study area. Action seven is essential to improvement in the lower portion of the study area below the Newton WWTP. The remaining actions would also be extremely useful, but will result in limited improvement unless the first seven are also accomplished.

1. **Over the long run, extensive stream channel restoration activities and stormwater retrofit BMPs should be implemented throughout the watershed.** This will involve a substantial effort that would likely take several decades to fully implement:
 - a) Approximately ten miles of Clark Creek within the study area (and another ten miles downstream of the study area), as well as many tributary channels, should be restored to a stable morphology.
 - b) BMPs to reduce stormwater runoff volume and partially restore watershed hydrology should be implemented in the existing developed areas of the Clark headwaters, Miller Branch, Cline Creek, Hildebran Creek and Town Creek drainages.

2. **These activities should be implemented deliberately and incrementally over time.**
 - a) Work should be carried out first in tributary and headwaters subwatersheds. Restoration of the mainstem of Clark Creek should be approached later when upstream sediment sources have been reduced and upstream hydrologic conditions have been mitigated to the extent practical.
 - b) Channel restoration and stormwater BMPs should be implemented in an integrated fashion so that both channel morphology and watershed hydrology problems are addressed using a coordinated approach in each subwatershed.
 - c) Local governments and other stakeholders should develop the cooperative organizational framework necessary to carry out the watershed planning, project design, implementation and monitoring activities that will be necessary to sustain this effort over time.
3. **The five-square mile Cline Creek subwatershed should serve as the focus for initial planning and project activities.** Costs are likely to exceed \$1 million per square mile of watershed. Activities should include:
 - a) Restoring the mainstem of Cline Creek to a stable morphology from at least US 321 to its mouth, a distance of approximately 1.5 miles.
 - b) Evaluating and implementing channel restoration opportunities on major tributaries.
 - c) Implementing stormwater BMPs to control runoff volume and peak flows from existing developed areas, especially commercial and industrial areas upstream of US 321. The selection of specific BMP types and locations will require watershed planning and site-specific engineering evaluations.
 - d) Encouraging property owners along all streams to replant native riparian vegetation.
4. **Post-construction stormwater management should be required for all new development in the study area in order to prevent further channel erosion and continued habitat degradation** due to additional uncontrolled stormwater inputs. These requirements should include active promotion of infiltration practices and other approaches to limit stormwater volume and no net increase in peak flows over predevelopment conditions for the 1-year 24-hour storm. Measures could be implemented through the Phase II stormwater program or through other local initiatives.
5. Whether accomplished through incentives or regulatory measures, **it is important that existing riparian buffers be protected.**
6. **In order to prevent future water quality deterioration related to new construction activities, sediment and erosion control practices should be improved.** The Division of Land Resources and the City of Newton's Erosion and Sediment Control Program should review their current tools and implementation to determine how erosion and sedimentation control efforts can be improved in this watershed.
7. The Division of Water Quality should ensure that chlorine concentrations in the Newton WWTP effluent are reduced to nontoxic levels. This facility should receive a chlorine limit as soon as possible, and in-stream chlorine concentrations should be carefully evaluated to determine if further action is necessary.

8. The headcut in Clark Creek near the Martin Marietta quarry, of unknown origin, should be stabilized to prevent further erosion and sediment loading to the stream.
9. A watershed education program should be developed and implemented with the goal of targeting homeowners and managers of commercial and industrial facilities in order to reduce current stream damage and prevent future degradation. At a minimum the program should include elements to address the following issues:
 - a) redirecting downspouts to pervious areas rather than routing these flows to driveways or gutters;
 - b) protecting existing wooded riparian areas on ephemeral streams;
 - c) replanting native riparian vegetation on perennial, intermittent and ephemeral channels where such vegetation is absent; and
 - d) reducing and properly managing pesticide and fertilizer use.
10. Additional data should be obtained to more narrowly define the nature and source of toxicants impacting the headwaters of Clark Creek. Periodic monitoring of the headwaters area should be carried out to determine if other ongoing activities (elimination of illegal discharges by Hickory as part of the Phase II stormwater program; BMPs intended to control stormwater volumes) lead to improvements in the benthic community.

Section 9

References

- Anacostia Restoration Team. 1991. *A Commitment to Restore Our Home River: A Six-Point Action Plan to Restore the Anacostia River*. Metropolitan Washington Council of Governments
- ASCE. 2001. *Guide for Best Management Practice (BMP) Selection in Urban Developed Areas*. Urban Water Infrastructure Management Committee's Task Committee For Evaluating Best Management Practices. American Society of Civil Engineers. Reston, Virginia.
- Bales, J.D., J.C. Weaver, and J.B. Robinson. 1999. *Relation of Land Use to Streamflow and Water Quality at Selected Sites in the City of Charlotte and Mecklenburg County, North Carolina, 1993-98*. USGS Water-Resources Investigations Report 99-4180. Raleigh, NC.
- Baltimore County Department of Environmental Protection and Resource Management. 1997. *Back River Watershed Water Quality Management Plan*. Baltimore County, MD. January.
- Bledsoe, B.P. and C.C. Watson. 2001. *Effects of Urbanization on Channel Instability*. JAWRA. 37:255-270.
- Brewer, E.O. 1975. *Soil Survey of Catawba County, North Carolina*. USDA Soil Conservation Service.
- Brookes, A. 1988. *Channelized Rivers: Perspectives for Environmental Management*. John Wiley & Sons. Chichester, UK.
- Burton, G.A. and R.E. Pitt. 2001. *Stormwater Effects Handbook: A Toolbox for Watershed Managers, Scientists and Engineers*. Lewis Publishers. Boca Raton.
- Caraco, D. et al. 1998. *Rapid Watershed Planning Handbook: A Comprehensive Guide for Managing Urban Watersheds*. Center for Watershed Protection. October. Ellicott City, MD.
- Catawba County. 1999. *Catawba County Strategic Growth Plan*.
- Cave, K.A. and D.A. Bryson. 2001. *Stormwater Control Using a Watershed Management Plan*. Stormwater Vol 2 No 7 (Nov/Dec). Online at <http://www.forester.net/sw>.
- CH2M HILL. 1998. *East Watersheds Impacts Assessment*. Metro Atlanta Urban Watersheds Initiative. Prepared for Atlanta Dept. of Public Works. CH2M HILL. Atlanta.
- City of Austin. 2001. *Watershed Protection Master Plan. Phase 1 Watersheds Report*. Executive Summary. Available on line at <http://www.ci.austin.tx.us/watershed/masterplan.htm>.
- Claytor, R.A. 1999. *An Eight-Step Approach to Implementing Stormwater Retrofitting*. Pp 212-218 in National Conference on Retrofit Opportunities for Water Resource Protection in Urban Environments. Proceedings of Conference held February 9-12, 1998 in Chicago IL. EPA/625/R-99/002.
- Darby, S.E. and A. Simon (eds). 1999. *Incised River Channels: Processes, Forms, Engineering and Management*. John Wiley & Sons. Chichester, UK.

- Ferguson, B.K. 1997. *The Alluvial Progress of Piedmont Streams*. Pp 132-143 in L.A. Roesner (ed) *Effects of Watershed Development and Management on Aquatic Ecosystems*. ASCE. New York.
- Ferguson, B., R. Pinkham and T. Collins. 1999. *Re-Evaluating Stormwater: The Nine Mile Run Model for Restorative Redevelopment*. Rocky Mountain Institute. Snowmass, CO.
- Foran, J.A. and S.A. Ferenc. 1999. *Multiple Stressors in Ecological Risk and Impact Assessment*. SETAC Press. Society for Ecological Toxicology and Chemistry. Pensacola.
- Fox, G.A. 1991. *Practical Causal Inference for Ecoepidemiologists*. J Toxicol Environ Health. 33:359-373.
- Frissell, C.A. 1997. *Ecological Principles*. Pp 96-115 in J.E. Williams, C.A. Wood and M.P. Dombeck (eds) *Watershed Restoration: Principles and Practices*. American Fisheries Society. Bethesda, MD.
- Galli, J. 1999. *Monitoring the Effectiveness of Urban Retrofit BMPs and Stream Restoration*. Pp 48-53 in National Conference on Retrofit Opportunities for Water Resource Protection in Urban Environments. Proceedings of Conference held February 9-12, 1998 in Chicago IL. EPA/625/R-99/002.
- Giese, G.L. and R.R. Mason. 1991. *Low-Flow Characteristics of Streams in North Carolina*. USGS Open-File Report 90-399. United States Geological Survey. Raleigh.
- Haupt, M., J. Jurek, L. Hobbs, J. Guidry, C. Smith and R. Ferrell. 2002. *A Preliminary Analysis of Stream Restoration Costs in the North Carolina Wetlands Restoration Program*. Paper presented at the conference Setting the Agenda for Water Resources Research. April 9, 2002. Raleigh, NC.
- Healy, R.G. 1985. *Competition for Land in the American South*. Conservation Foundation. Washington, DC.
- Horner, R.R., J.J. Skupien, E.H. Livingston, and H.E. Shaver. 1994. *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*. Terrene Institute. Washington DC.
- Jacobson, R.B. and D.J. Coleman. 1986. *Stratigraphy and Recent Evolution of Maryland Piedmont Flood Plains*. American J of Science. 286:617-637.
- Livingston, E.H. 2000. *Lessons Learned about Successfully Using Infiltration Practices*. Pp 81-96 in National Conference on Tools for Urban Water Resource Management and Protection. Proceedings of Conference held February 7-10, 2000 in Chicago, IL. EPA/625/R-00/001.
- Louder, D.E. 1964. *Survey and Classification of the Catawba River and Tributaries, North Carolina*. Final Report. Federal Aid in Fish Restoration. Job I-H, Project F-14-R. North Carolina Wildlife Resources Commission. Raleigh, NC.
- Maxted, J.R. and E. Shaver. 1999. *The Use of Retention Basins to Mitigate Stormwater Impacts to Aquatic Life*. Pp 6-15 in National Conference on Retrofit Opportunities for Water Resource Protection in Urban Environments. Proceedings of Conference held February 9-12, 1998 in Chicago IL. EPA/625/R-99/002.

- Maryland Department of the Environment. 2000. *2000 Maryland Stormwater Design Manual, Volumes I and II*.
- McGurrin, J. and H. Forsgren. 1997. *What Works, What Doesn't, and Why*. Pp 459-471 in J.E. Williams, C.A. Wood and M.P. Dombeck (eds) *Watershed Restoration: Principles and Practices*. American Fisheries Society. Bethesda, MD.
- Meade, R.H. 1982. *Sources, Sinks and Storage of River Sediment in the Atlantic Drainage of the United States*. J of Geology. 90:235-252.
- Meade, R.H. and S.W. Trimble. 1974. *Changes in Sediment Loads in Rivers of the Atlantic Drainage on the United States Since 1900*. Pp 99-104. International Assoc of Hydrological Sciences Publ. No. 113.
- Metropolitan Washington Council of Governments. 1998. *Anacostia Watershed Restoration Progress and Conditions Report, 1990-1997*. May.
- Montgomery County Department of Environmental Protection. 2001. *Countywide Stream Protection Strategy*. Available online at <http://www.co.mo.md.us/dep/Watersheds/csps/csps.html>.
- NCDWQ. 1998. *North Carolina Ceriodaphnia Chronic Effluent Toxicity Procedure*. December 1985, Revised February 1998.
- NCDWQ. 1999a. *Catawba River Basinwide Water Quality Management Plan*. Water Quality Section. December.
- NCDWQ. 1999b. *Review of Toxics Information for the Clark Creek Watershed, Catawba River Basin*. Draft. Division of Water Quality. March.
- NCDWQ. 1999c. *Stormwater Best Management Practices*. Water Quality Section. April.
- NCDWQ. 2000. *A Citizen's Guide to Water Quality Management in North Carolina*. First Edition. Planning Branch.
- NCDWQ. 2001a. *Standard Operating Procedures for Chemical/Physical Toxicity Monitoring*. Watershed Assessment and Restoration Project.
- NCDWQ. 2001b. *Standard Operating Procedures—Biological Monitoring*. Biological Assessment Unit.
- NCSU. 2001. *Morphological Evaluation and Restoration Feasibility Assessment: Clark Creek in Newton, NC*. North Carolina State University. Stream Restoration Institute. Raleigh. November.
- NCSU. 2002a. *Morphological Evaluation and Restoration Feasibility Assessment: Clark Creek at the Martin Marieta Quarry in Hickory, NC*. North Carolina State University. Stream Restoration Institute. Raleigh. January.
- NCSU. 2002b. *Morphological Evaluation and Restoration Feasibility Assessment: Cline Creek above Old St. Pauls Church Road (SR 1164), in Newton, NC*. North Carolina State University. Stream Restoration Institute. Raleigh. February.

- Niemi, G.J., P. DeVore, N. Detenbeck et al. 1990. *Overview of Case Studies on Recovery of Aquatic Systems from Disturbance*. Environmental Management. 14:571-587.
- Preslar, C.J. 1954. *A History of Catawba County*. Rowan Printing Company. Salisbury, NC.
- Prince George's County Department of Environmental Resources. 2000. *Low Impact Development Design Strategies: An Integrated Design Approach*. USEPA. EPA 841/B-00/003. January.
- Reckhow, K.H. 1997. *Adaptive Management: Responding to a Dynamic Environment*. WRI News. Number 307. September/October. P 2-3. Water Resources Research Institute of the University of North Carolina.
- Richter, D.D., K. Korfmacher, and R. Nau. 1995. *Decreases in Yadkin River Basin Sedimentation: Statistical and Geographic Time-Trend Analyses, 1951 to 1990*. Report No. 297 Water Resources Research Institute of the University of North Carolina. Raleigh. November.
- Rosgen, D. 1996. *Applied River Morphology*. Wildland Hydrology. Pagosa Springs, CO.
- Rosgen, D. 1997. *A Geomorphological Approach to Restoration of Incised Rivers*. Pp 12-22 in S.S.Y. Wang et al. (eds) *Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision*. Univ of Mississippi.
- Rouge River Project. 2002. *Overview Description of Watershed Management for the Rouge River*. Online at <http://www.wcdoe.org/rougeriver/watershed>.
- Schueler, T. 1994. *The Importance of Imperviousness*. Watershed Protection Techniques. 1:3:100-111.
- Schueler, T.R. 2000a. *The Environmental Impact of Stormwater Ponds*. Pp 443-452 in T.R. Schueler and H.K. Holland (eds) *The Practice of Watershed Protection*. Center for Watershed Protection. Ellicott City, MD.
- Schueler, T.R. 2000b. *The Economics of Stormwater Treatment: An Update*. Pp 61-65 in T.R. Schueler and H.K. Holland (eds) *The Practice of Watershed Protection*. Center for Watershed Protection. Ellicott City, MD.
- Schueler, T.R. and H.K Holland. 2000. *Sligo Creek: Comprehensive Stream Restoration*. Pp 716-721 in T.R. Schueler and H.K. Holland (eds) *The Practice of Watershed Protection*. Center for Watershed Protection. Ellicott City, MD.
- Schueler, T.R., J. Galli, L. Herson, P. Kumble and D. Shepp. 1991. *Developing Effective BMP Systems for Urban Watersheds*. Pp 33-63 in Anacostia Restoration Team (ed) *Watershed Restoration Sourcebook*. Metropolitan Washington Council of Governments.
- Schumm, S.A., M.D. Harvey and C.C. Watson. *Incised Channels: Morphology, Dynamics and Control*. Water Resources Publications. Littleton, CO.
- Sedell, J.R., G.H. Reeves, F.R. Hauer, J.A. Stanford and C.P.Hawkins. 1990. *Role of Refugia in Recovery from Disturbances: Modern Fragmented and Disconnected River Systems*. Environmental Management. 14:711-724.

- Simmons, C.E. 1993. *Sediment Characteristics of North Carolina Streams, 1970-79*. USGS Water-Supply Paper 2364 [Originally published in 1987 as Open-File Report 87-701].
- Simon, A. 1989. *A Model of Channel Response in Disturbed Alluvial Streams*. *Earth Surface Processes and Landforms*. 14:11-26.
- Simon, A. and S. Darby. 1999. *The Nature and Significance of Incised River Channels*. Pp 3-18 in S. Darby and A. Simon (eds), *Incised River Channels: Processes, Forms, Engineering and Management*. John Wiley & Sons. Chichester, UK.
- Stahl, J.E. 2001. *Managing Stormwater in Charlotte, North Carolina: An Innovative Approach*. *Stormwater Vol 2 No 6* (Sept/Oct). Online at <http://www.forester.net/sw>.
- Trimble, S.W. 1975. *Denudation Studies: Can We Assume Stream Steady State?* *Science*. 188:1207-1208.
- Trimble, S.W. 1974. *Man-Induced Soil Erosion on the Southern Piedmont 1700-1970*. Ankeny, IA. Soil and Water Conservation Society of America.
- USEPA. 1993. *Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms*. Fourth Edition. EPA/600/4-90/027F.
- USEPA. 1995. *Final Water Quality Guidance for the Great Lakes System*. 40 CFR Parts 9, 122, 123, 131, 132. Federal Register. 60:56:15365-15425. March 23.
- USEPA. 1997. *Guidelines for Preparation of the Comprehensive State Water Quality Assessments [305(b) Reports] and Electronic Updates: Supplement*. EPA 841-B-97-002B. September.
- USEPA. 1998. *Guidelines for Ecological Risk Assessment*. EPA 630-R-95-002F.
- USEPA. 1999. *National Recommended Water Quality Criteria--Correction*. EPA 822-Z-99-001.
- USEPA. 2000. *Stressor Identification Guidance Document*. EPA 822-B-00-025. December.
- USEPA. 2001. *Protecting and Restoring America's Watersheds: Status, Trends, and Initiatives in Watershed Management*. EPA 840-R-00-001. June.
- Weinkam, C., R. Shea, C. Shea, C. Lein and D. Harper. 2001. *Urban Stream Restoration Programs of Two Counties in the Baltimore-Washington D.C. Area*. Paper Presented at the Fourth Annual North Carolina Stream Restoration Conference, Stream Repair and Restoration: A Focus on the Urban Environment. October 16-19, 2001. Raleigh, NC.
- Wenger, S. 1999. *A Review of the Scientific Literature on Riparian Buffer Width, Extent and Vegetation*. Office of Public Service and Outreach. Institute of Ecology. University of Georgia. Athens.
- Wilson, M.P. 1983. *Erosion of Banks Along Piedmont Urban Streams*. Water Resources Research Institute of the University of NC. Raleigh. Report No. 189.

- Yoder, C.O. and E.T. Rankin. 1995. *Biological Response Signatures and the Area of Degradation Value: New Tools for Interpreting Multimetric Data*. Pp 263-286 in W.S. Davis and T.P. Simon (eds) *Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making*. Boca Raton, FL. Lewis Publishers.
- Yount, J.D. and G.J. Niemi. 1990. *Recovery of Lotic Communities and Ecosystems from Disturbance—A Narrative Review of Case Studies*. *Environmental Management*. 14:547-569